"Damping of Beams with Inserts"

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering

By
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CERTIFICATE

This is to certify that thesis entitled, "**PROJECT ON DAMPING OF BEAMS WITH INSERTS**" submitted by **Abhishek Ray Mohapatra** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/ institute for award of any Degree or Diploma.

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ABSTRACT

The purpose of this project is to predict damping effect using beams with inserts for passive damping. This method of passive damping treatment is widely used for structural application in many industries like automobile, aerospace, etc. The experiment is to be carried out to compare the damping of the material without inserts and with inserts of different visco-elastic materials of circular cross sections.

The specimens are prepared from commercial mild steel and Teflon, Bakelite, Perspex as inserts.

The experiment results are shown and from the results it has been concluded that the inserts of high damping capability in the structures increases the damping characteristics of the structure. The graphs obtained from the oscilloscope shows damping of the beams.

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

INTRODUCTION

Noise and vibration control is a major concern in several industries such as aeronautics and automobiles. The reduction of noise and vibrations is a major requirement for performance, sound quality, and customer satisfaction. Passive damping technology [1.1] using viscoelastic materials are classically used to control vibration. Use of high damping capacity inserts in structures of low damping characteristics is becoming popular.

The growing use of such structures has motivated many authors to intensify the study of their vibration and acoustic performance and the design of inserted damped structures. This kind of structures has appeared recently as a viable alternative. It has been shown that this class of materials enables manufacturers to cut weight and cost while providing noise, vibration and harshness performance. Inserted structures are now applied in almost all industrial fields.

1.1 Background

Damping is the energy dissipation properties of a material or system under cyclic stress. It is an effect that tends to reduce the amplitude of oscillations in an oscillatory system, particularly the harmonic oscillator.

Active damping:

Active damping [18, 20] refers to energy dissipation from the system by external means, such as controlled actuator, etc. Due to their lack of versatility, passive damping and cancellation strategies become ineffective when the dynamics of the system and/or the frequencies of the disturbance vary with time. Not to mention that active systems can potentially provide increased effectiveness in controlling vibration compared to passive approaches. And, some applications do not lend themselves to have large passive vibration control appendages, such as a tuned mass damper, attached to them. Active damping and cancellation control can address these two concerns. Due to remarkable advances in sensor, actuator, and more importantly computer technologies in recent years active systems have become cost effective sloutions to most sound and vibration control problems.

Passive damping:

Passive damping [18, 20] refers to energy dissipation within the structure by add-on damping devices such as isolator inserts, by structural joints and supports, or by structural member's internal damping. The most commonly applied vibration control techniques are based on the use of passive technologies. The majority of these applications are based on passive damping using viscoelastic materials for vibration control and sound absorbing materials. Although most passive damping treatments are inexpensive to fabricate, their successful application require a thorough understanding of the vibration problem in hand and the properties of the damping materials. Viscous dampers (dashpots), tuned-mass dampers, dynamic absorbers, shunted piezoceramics dampers, and magnetic dampers are other mechanisms of passive vibration control. Passive sound and vibration control has its limitations such as: lack of versatility, large size and weight when used for low-freqeuncy vibration control.

Material damping:

Energy dissipation in a volume of macro-continuous media.

System damping:

Energy dissipation in the total structure. In addition to damping due to materials, it also includes energy dissipation effects of joints, fasteners, and interfaces

1.2 Factors affecting the damping capacity of the structure are:

- Frequency and amplitude of excitation
- Kinematic co-efficient of friction at the interfaces
- Size and shape of the inserts, bolts, rivets, viscoelastic material etc.
- Intensity of interface pressure

1.3 Techniques adapted to improve the damping capacity of structures are:

- Use of constrained/unconstrained viscoelastic layers
- Fabrication of multilayered sandwich construction
- Insertion of special high elastic inserts in the parent structures
- Application of spaced damping techniques
- Fabricating layered and jointed structures with welded/riveted/bolted joint

1.4 Vibration problem and evolution of passive damping technology

The damping of structural components and materials is often a significantly overlooked criterion for good mechanical design. The lack of damping in structural components has led to numerous mechanical failures over a seemingly infinite multitude of structures. For accounting the damping effects, lots of research and efforts have been done in this field to suppress vibration and to reduce the mechanical failures. Since it was discovered that damping materials could be used as treatments in passive damping technology to structures to improve damping performance, there has been a flurry of ongoing research over the last few decades to either alter existing materials, or developing entirely new materials to improve the structural dynamics of components to which a damping material could be applied. The most common damping materials available on the current market are viscoelastic materials. Viscoelastic materials are generally polymers, which allow a wide range of different compositions resulting in different material properties and behavior. Thus, viscoelastic damping materials can be developed and tailored fairly efficiently for a specific application.

1.5 Objective of the present work

The dynamic load carrying capacity of the strip can be increased by use of inserts. Proper introduction of stress concentration into structural members can considerably increase their damping capacities and dynamic rigidities with minor sacrifice in their static rigidities. Better damping characteristics can be achieved when structural members are fitted with ring-type elastic inserts of materials having higher damping capacities, almost without sacrificing any static rigidity or slightly compromising with strength of the structure. Proper combination of beam/strip and insert materials, the increase in damping could be high enough so as to offset the effect of stress concentration. Theoretically increase in the damping capacity [2] has been expressed as the equivalent logarithmic decrement of the specimen with undisturbed or the insert-free specimen. By conducting experiment the logarithmic decrement of amplitude of oscillation can be found out from which it can also be proved that the inserts of viscoelastic material enhance the damping property of beam or strip.

CHAPTER 2

LITERATURE SURVEY

2.1Logarithmic Decrement

The logarithmic decrement [13] is defined as the natural logarithm of ratio of any two successive amplitudes; $\delta = \frac{1}{n} \ln \left(\frac{y_1}{y_n}\right)$.

Amount of damping present in system can be measured by measuring the rate of decay of free oscillations. The larger the damping, the greater will be the rate of decay.

The general equation of the damping vibration:

$$\mathcal{Y} = ye^{-\zeta\omega t} \sin\left(\left(\sqrt{1-\zeta^2}\right)\omega t + \phi\right)$$

So, logarithmic decrement between two successive amplitudes becomes;

$$\delta = \ln\left(\frac{y_1}{y_2}\right) = \ln e^{\zeta\omega\tau} = \zeta\omega\tau$$

where τ is the damped time period,

ζ is the damping ratio,

ϕ is the phase difference

Damped time period $\tau = \frac{2\pi}{\omega\sqrt{1-\zeta^2}}$

So, $\delta = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}} \cong 2\pi\zeta$ as $\sqrt{1-\zeta^2} \cong 1$

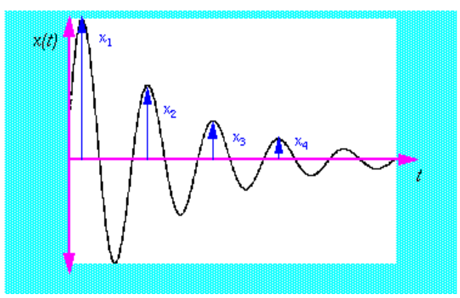

Fig. 1: Amplitude time graph of damped oscillation

2.2 Stress-Damping Relationship

For a uniaxial stress-system, the energy dissipated by the material per unit volume per cycle [2] is given by

$$D_v = J\sigma^n, \tag{1}$$

Where σ is the stress-amplitude and J and n are material constants. In the case of a multi- axial stress-system, Hooker proposed an equivalent stress-amplitude σ_{eq}, such that

$$D_v = J\sigma_{eq}^n = J(\sigma_{eq}^2)^{n/2}, \tag{2}$$

Where,

$$\sigma_{eq}^2 = (1 - \lambda_1)(\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1) + \\ + \lambda_1(\sigma_1 + \sigma_2 + \sigma_3)^2, \tag{3}$$

σ_1, σ_2, σ_3 being the principal stresses and I, being a curve-fitting parameter signifying the contribution of dilatational energy towards damping. Taking λ_1 equal to zero

$$\sigma_{eq}^2 = \underset{x}{\sigma_r^2} + \underset{y}{\sigma_\theta^2} + \sigma_z^2 - \underset{x}{\sigma_r}\underset{y}{\sigma_\theta} - \underset{y}{\sigma_\theta}\sigma_z - \sigma_z\underset{x}{\sigma_r} + 3(\underset{xy}{\tau_{r\theta}^2} + \underset{y}{\tau_{\theta z}^2} + \underset{x}{\tau_{zr}^2}). \tag{4}$$

Once σ_{eq} has been found, the damping energy dissipated per cycle by the whole specimen can be obtained by the volume integration of equation (1):

$$D = \iiint_V D_v \, dv. \tag{5}$$

The damping capacity is expressed in terms of the logarithmic decrement,

$$\delta = D/2W, \tag{6}$$

Where W is the maximum elastic energy during the cycle. W can be calculated from the stress field in the following manner. The elastic energy per unit volume is

$$W_v = \frac{1}{2E}\left[\sigma_{\underset{x}{r}} + \sigma_{\underset{y}{\theta}} + \sigma_z\right]^2 - \frac{(1+\nu)}{E}\left[\sigma_{\underset{x}{r}}\sigma_{\underset{y}{\theta}} + \sigma_{\underset{y}{\theta}}\sigma_z + \sigma_z\sigma_{\underset{x}{r}} - \tau^2_{\underset{xy}{r\theta}} - \tau^2_{\underset{y}{\theta z}} - \tau^2_{\underset{x}{zr}}\right], \qquad (7)$$

E is the modulus of elasticity of the material and v is the Poisson's ratio of the

where material. The elastic energy of the whole specimen is given by

$$W = \iiint_V W_v \, dv. \qquad (8)$$

CHAPTER 3

EXPERIMENTATION

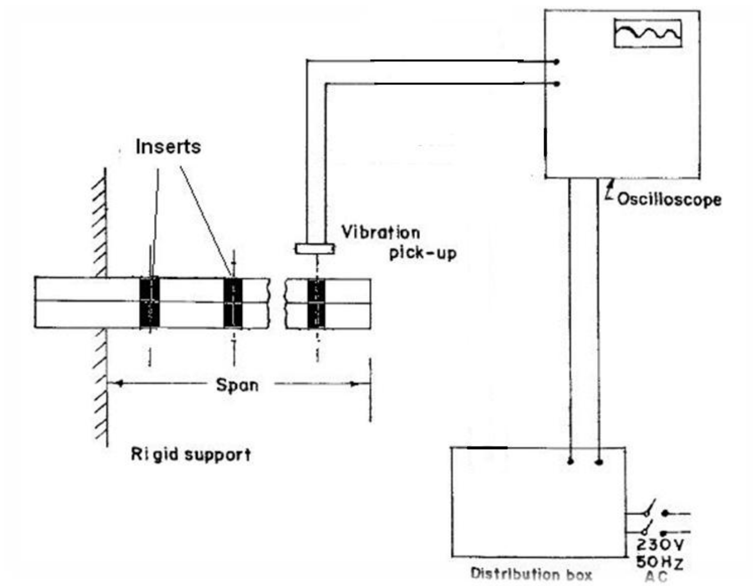

Fig. 2 Schematic layout of experimental setup

Fig. 3 Experimental Set-up

3.1 Instrumentation

In order to measure the logarithmic damping decrement, natural frequency of vibration of different specimen the following instruments were used as shown in circuit diagram figure:

1. Power supply unit
2. Vibration pick-up
3. Oscilloscope
4. Dial gauge

Oscilloscope

Display: - 8x10 cm. rectangular mono-accelerator c.r.o. at 2KV e.h.t. Trace rotation by front Panel present. Vertical Deflection: - Four identical input channels ch1, ch2, ch3, ch4.

Band-width: - (-3 db) d.c. to 20 MHz (2 Hz to 20 MHz on a.c.)

Sensitivity: - 2 mV/cm to 10 V/cm in 1-2-5 sequence.

Accuracy: - ± 3 %

Variable Sensitivity :-> 2.5 % 1 range allows continuous adjustment of sensitivity from 2mV/cm to V/cm.

Input impedance: - 1M/28 PF appx.

Input coupling: - D.C. and A.C.

Input protection: - 400 V d.c.

Display modes: - Single trace ch1 or ch2 or ch3 or ch4. Dual trace chopped or alternate modes automatically selected by the T.B. switch.

An oscilloscope measures two things:

• Voltage

• Time (and with time, often, frequency)

Fig.4 Oscilloscope

Vibration pick-up

- Type: - MV-2000.
- Specifications:-
- Dynamic frequency range :- 2 c/s to 1000 c/s
- Vibration amplitude: - ±1.5 mm max.
- Coil resistance :- 1000Ω
- Operating temperature :- 10ċ to 40 ċ
- Mounting :- by magnet
- Dimensions :- Cylindrical
- Length:-45 mm
- Diameter: - 19 mm
- Weight:- 150 gms

3.2 Specimen

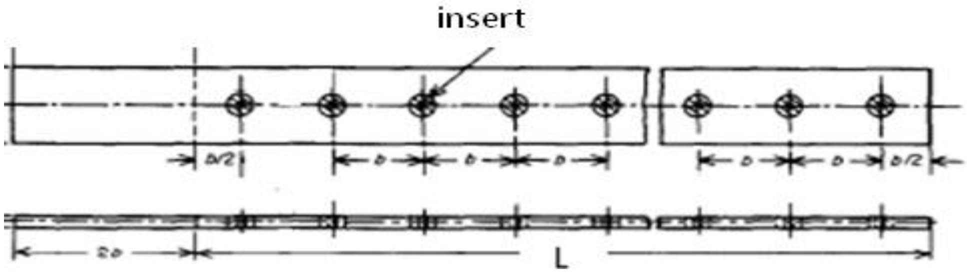

Fig.5: Schematic layout of specimen (b=35 mm, L=350 mm)

Fig.6: Teflon, Bakelite and Perspex Rods

Fig.7: Mild Steel Beam with Teflon inserts

Fig.8: Mild Steel Beam with Bakelite inserts

The specimens are prepared from commercial mild steel flats. To introduce inserts in them first the flats are drilled with specified dimensions. Then the Perspex, Bakelite and Teflon rods are used as inserts. The drilling is done by radial drill machine with 10 mm drilling tool. The gap between each successive insert is maintained to be 35 mm as nominal. The total length of the specimen is 500 mm, out of which 350 mm is the cantilever length. The width of the specimen is 40 mm and thickness is 5 mm.

3.3 Procedure

- The specimens prepared from commercial mild steel flats are combined with inserts.
- Distance between the consecutive connecting inserts to be kept equal (35 mm)
- Specimens are rigidly fixed to the support and the experiment is to be conducted.
- At the free end excitation is given to produce vibration in the beam.
- The free end deflection at the free end of the solid cantilever is measured by using the oscilloscope and will be compared with the original material.
- The difference between the original material damping and the damping with inserts gives the damping due to inserts.

3.4 Precautions

- The excitation or impulse to the beam should be given instantly.
- The beam should be rigidly fixed at the end.
- Inserts should be tightly fitted in the holes.
- Proper selection of the scale of measurement of the oscilloscope while measuring.
- The vibration pick up should be properly fixed to the specimen near the tip of the cantilever.

CHAPTER 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The graphs obtained from the oscilloscope during experiment are shown below:

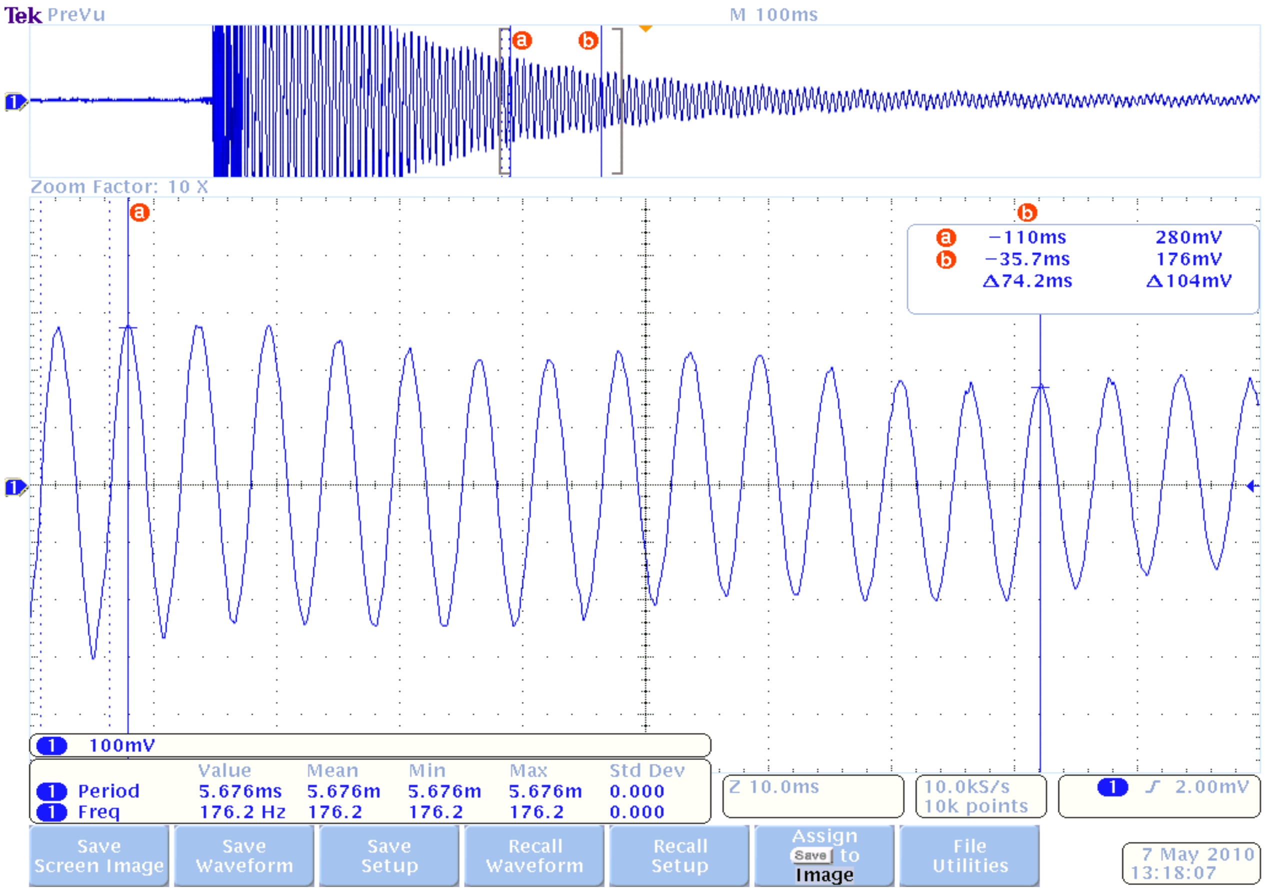

Fig 9: (section of Amplitude-Time graph of mild steel beam without any inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_0 = \frac{1}{n}\ln(y1/yn)$

From the Graph: 1 $y1$ = 280 mV

yn = 176mV

n = 13

Hence, $\delta_0 = \frac{1}{13}\, ln\, \left(\frac{280}{176}\right)$

$\delta_0 = 0.0357$

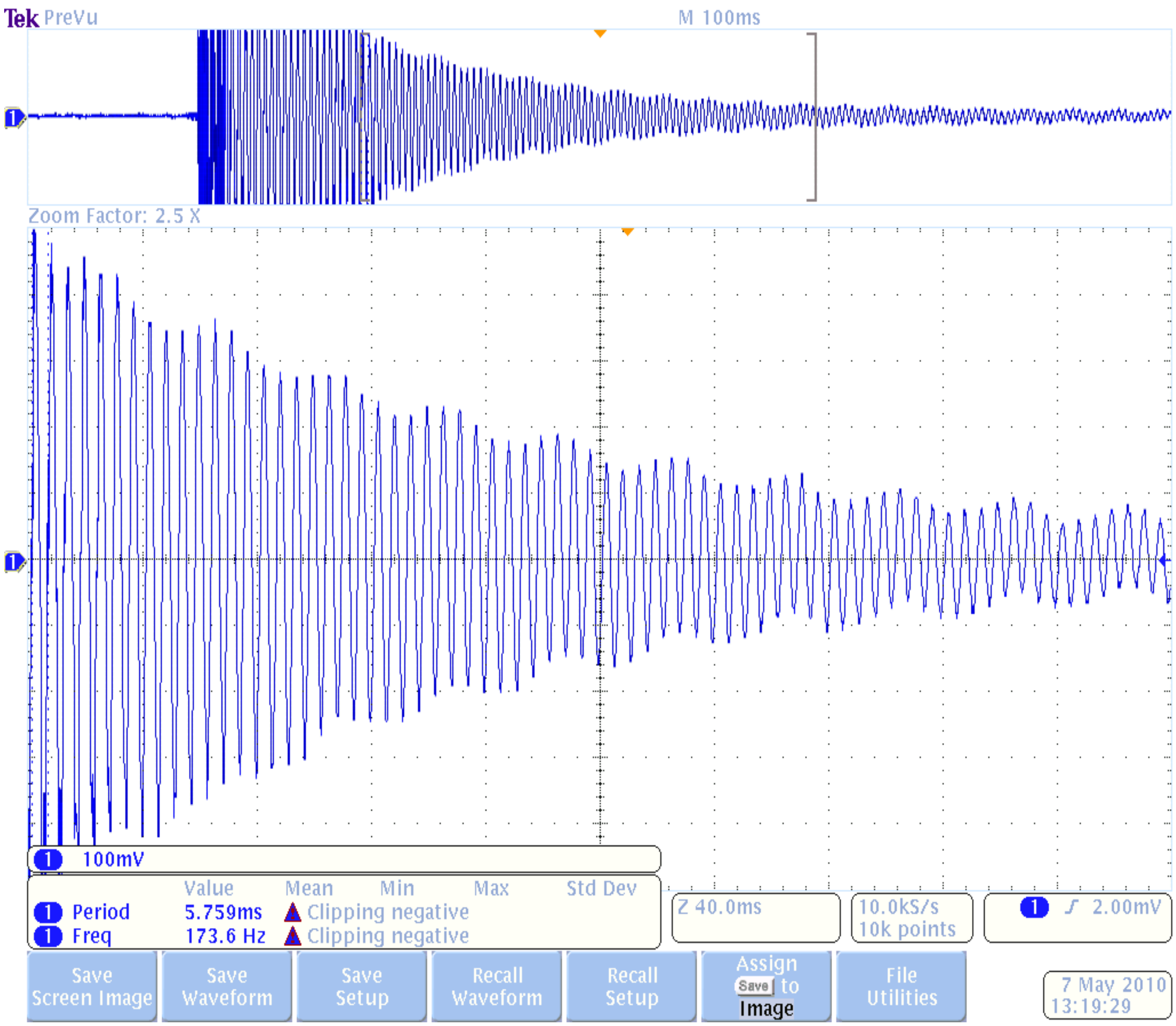

Fig 10: (Graph showing the damping of a mild steel beam)

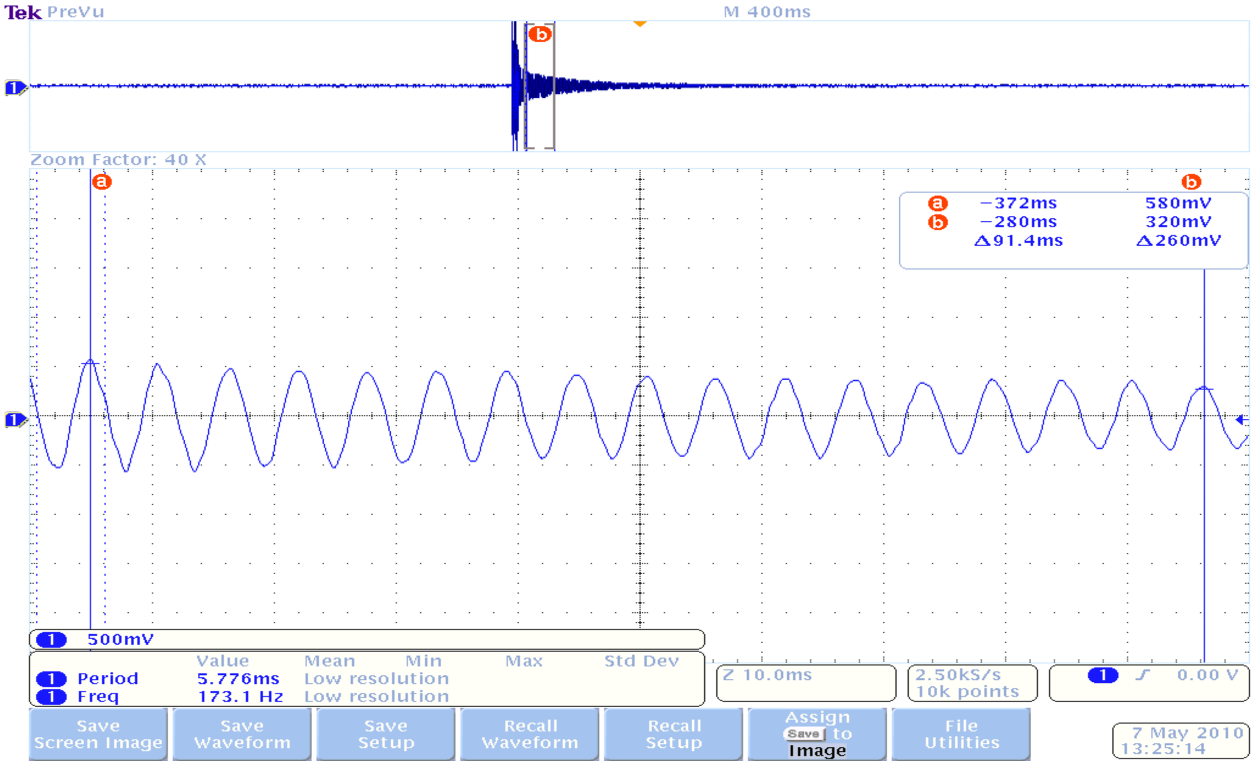

Fig 11: (section of Amplitude-Time graph of mild steel beam without any inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_0 = \frac{1}{n}\ln(\mathcal{Y}1/\mathcal{Y}n)$

From the Graph: 3 $\mathcal{Y}1$ = 580 mV

$\mathcal{Y}n$ = 320 mV

n = 13

Hence, $\delta_0 = \frac{1}{16} ln \left(\frac{580}{320}\right)$

δ_0 = 0.0371

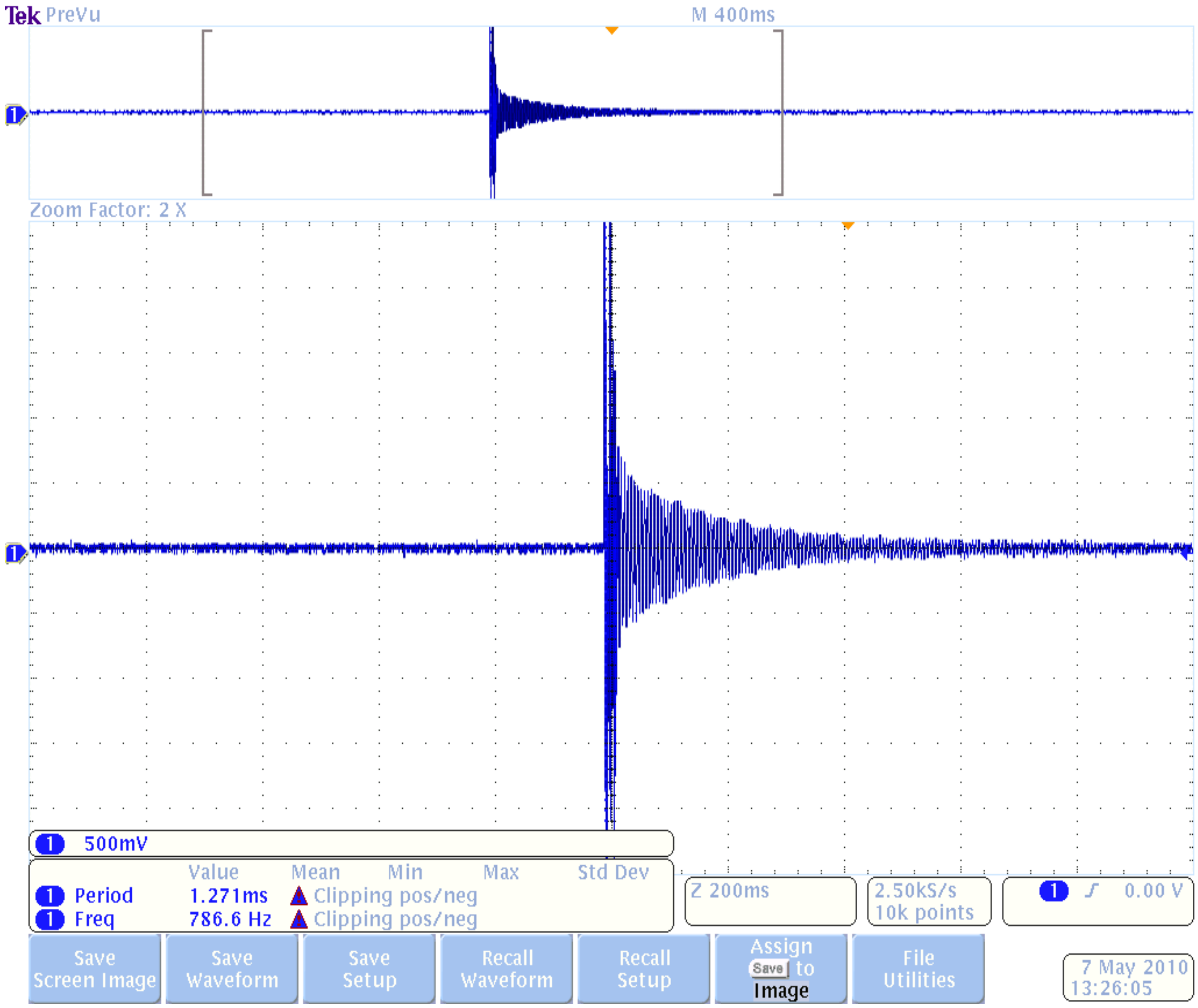

Fig 12: (Graph showing the damping of a mild steel beam)

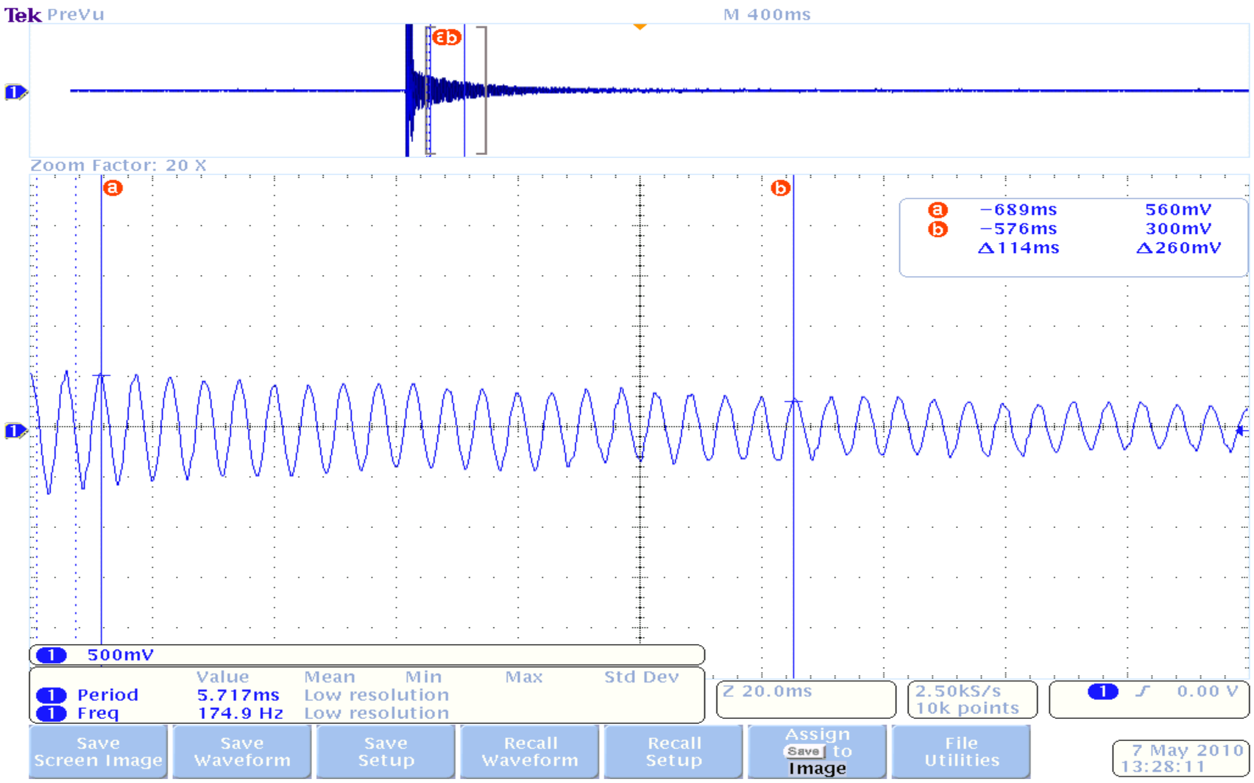

Fig 13: (section of Amplitude-Time graph of mild steel beam without any inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_0 = \frac{1}{n}\ln(y1/yn)$

From the Graph: 5 $y1$ = 560 mV

yn = 300 mV

n = 20

Hence, $\delta_0 = \frac{1}{20}\, ln\left(\frac{560}{300}\right)$

$\delta_0 = 0.0312$

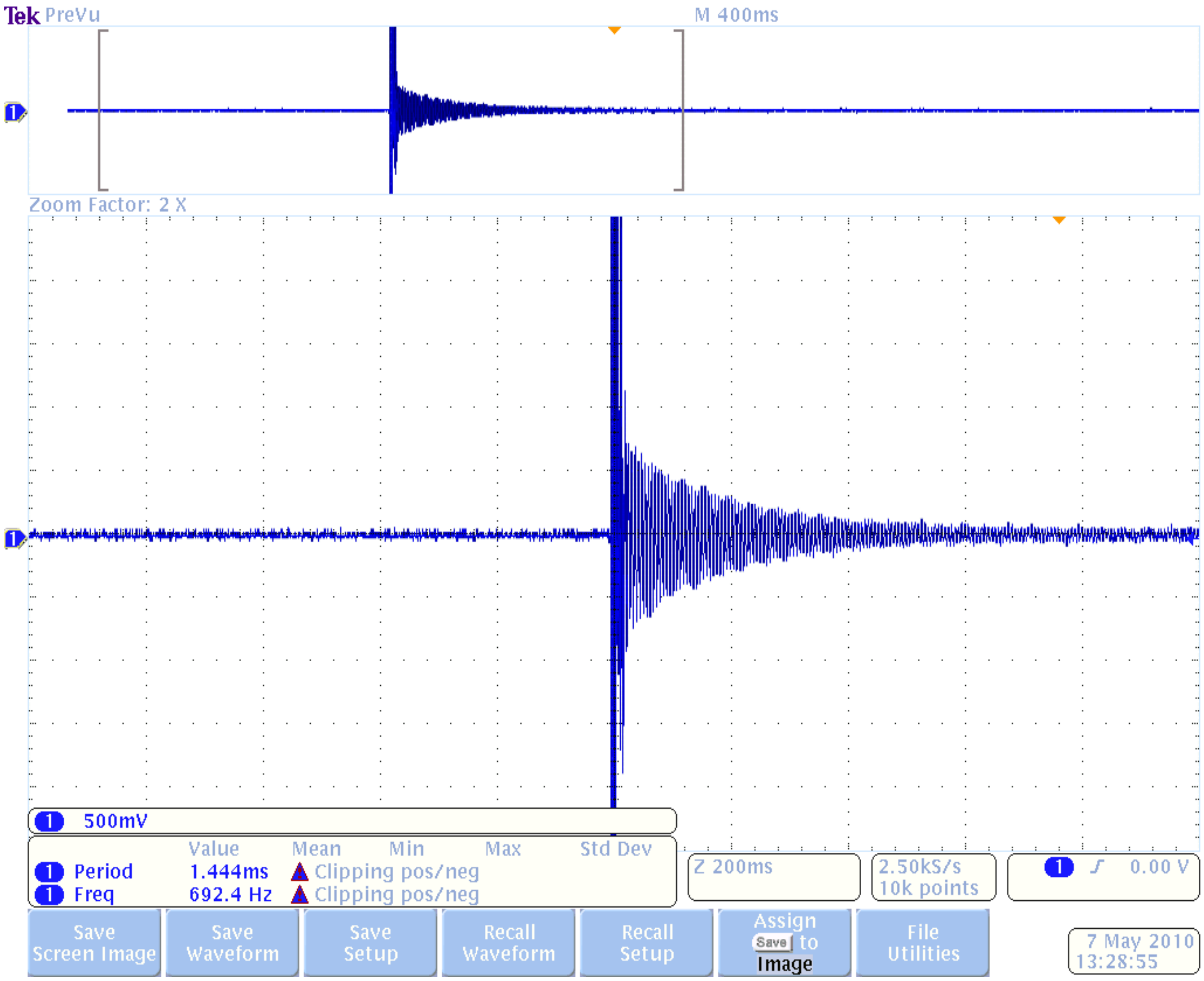

Fig 14: (Graph showing the damping of a mild steel beam)

Table 1:

OBSERVATION NO.	NATURAL FREQUENCY OF VIBRATION(hz)	TIME PERIOD (ms)	δ_0	MEAN δ_0
1	176.2	5.676	0.0357	0.0346
2	173.1	5.776	0.0371	
3	174.9	5.717	0.0312	

The logarithmic decrement of vibration of a mild steel beam without any inserts is found to be δ_0 = **0.0346**

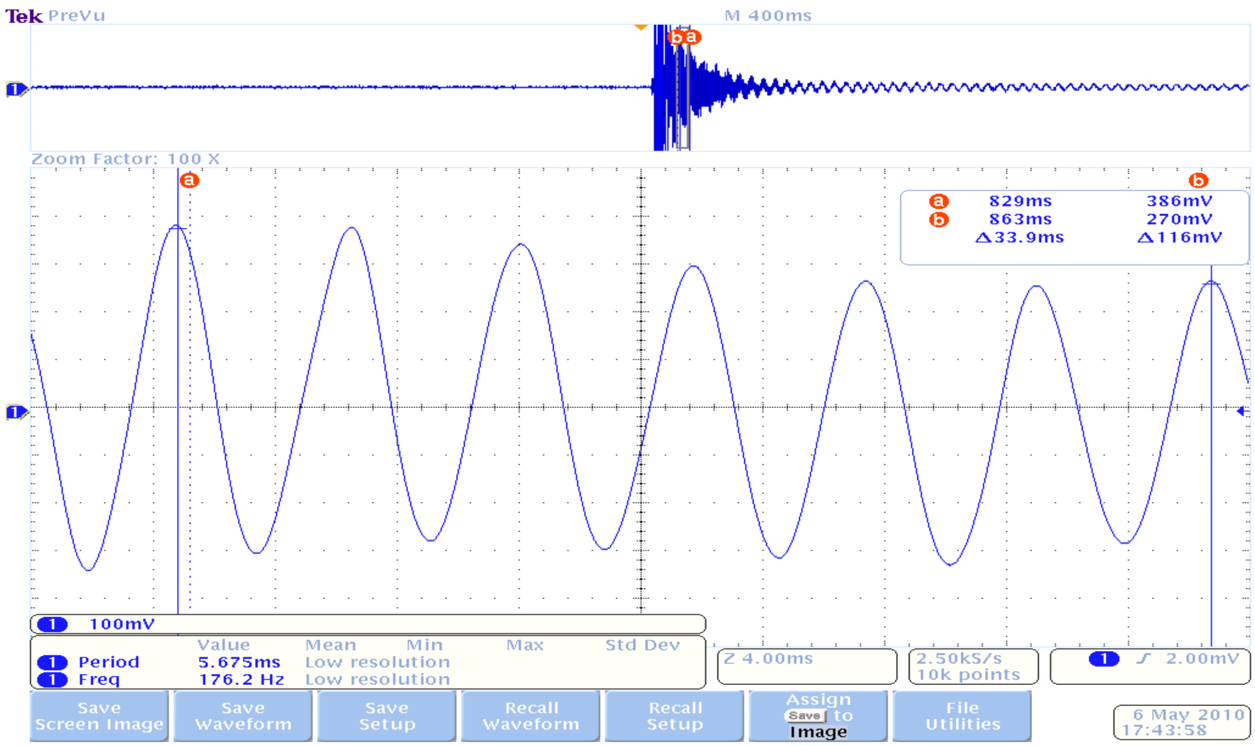

Fig 15: (section of Amplitude-Time graph of mild steel beam with Teflon inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_t = \frac{1}{n}\ln(y1/yn)$

From the Graph: 7 $y1$ = 386 mV

yn = 270 mV

n = 6

Hence, $\delta_t = \frac{1}{6} \ln \left(\frac{386}{270}\right)$

$\delta_t = 0.0595$

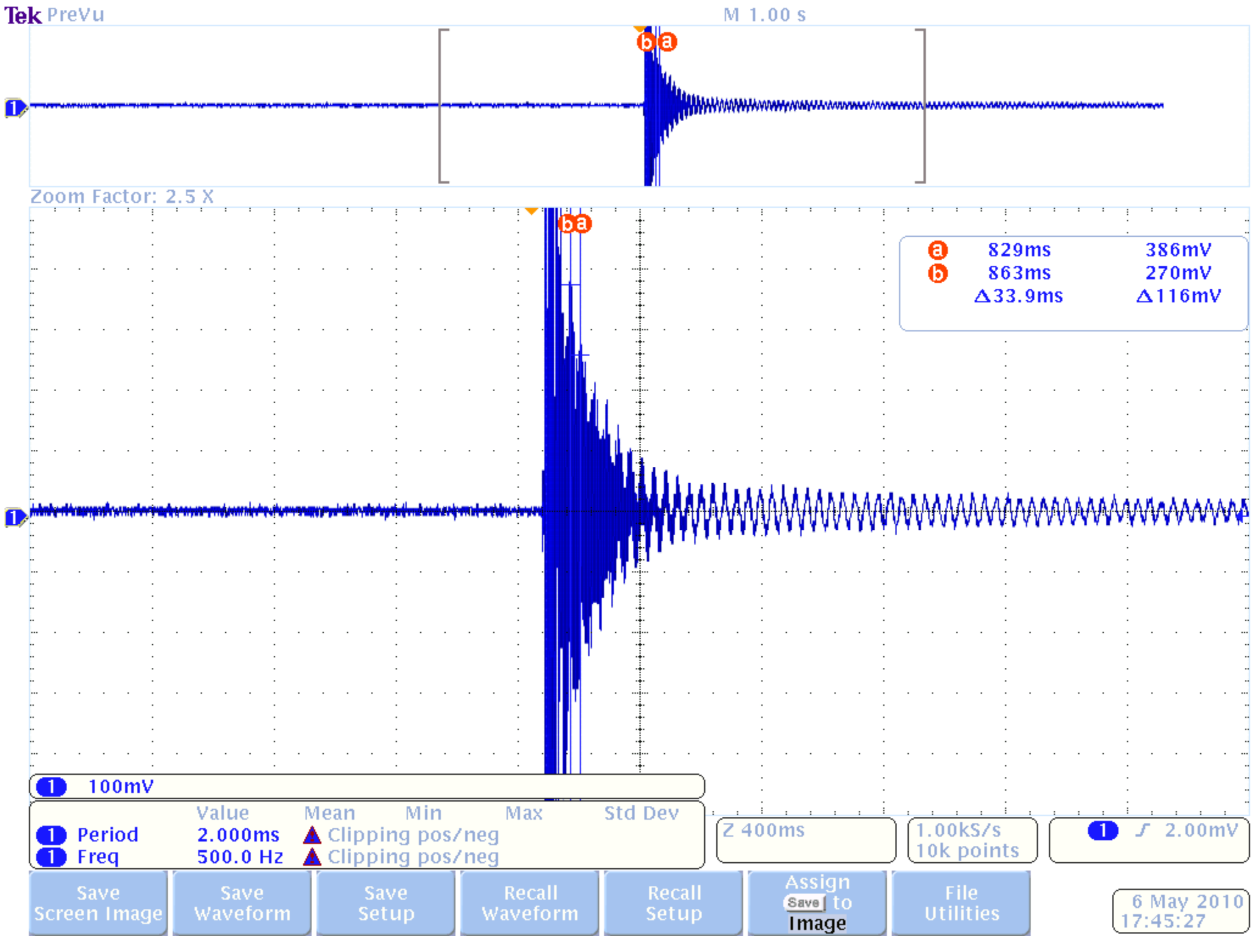

Fig 16: (Graph showing the damping of a mild steel beam with Teflon inserts)

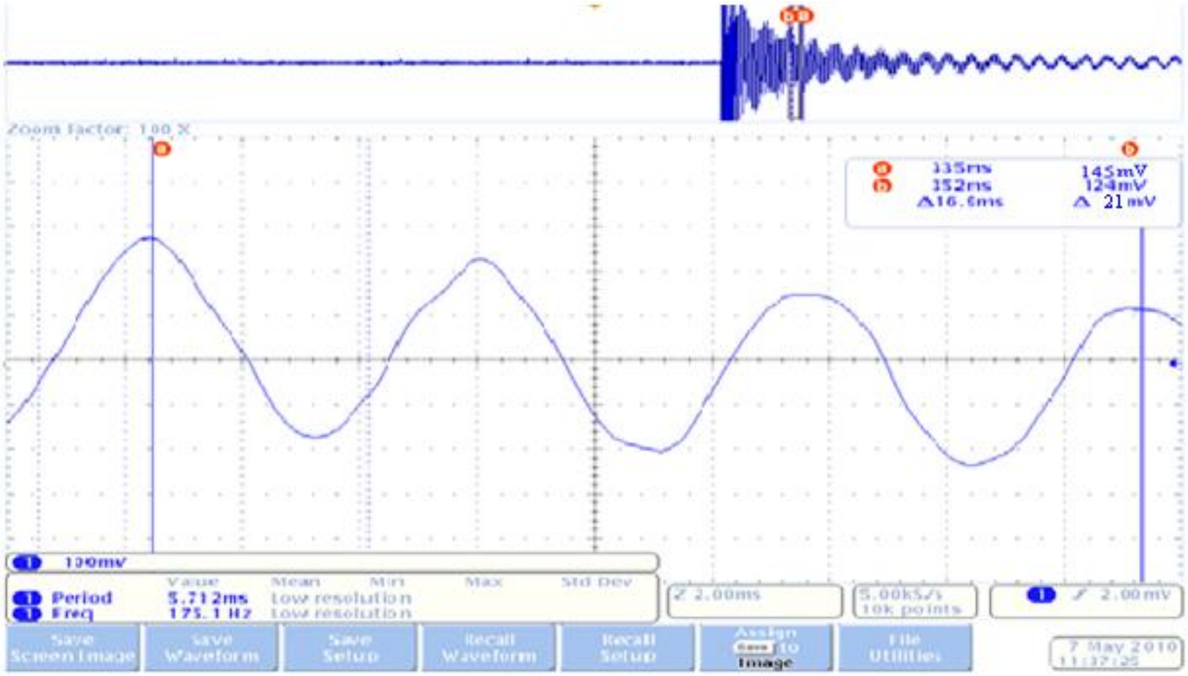

Fig 17: (section of Amplitude-Time graph of mild steel beam with Teflon inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_t = \frac{1}{n}\ln(y1/yn)$

From the Graph: 9 $y1$ = 145 mV

yn = 124 mV

n = 3

Hence, $\delta_t = \frac{1}{3} ln \left(\frac{145}{124}\right)$

$\delta_t =$ 0.0521

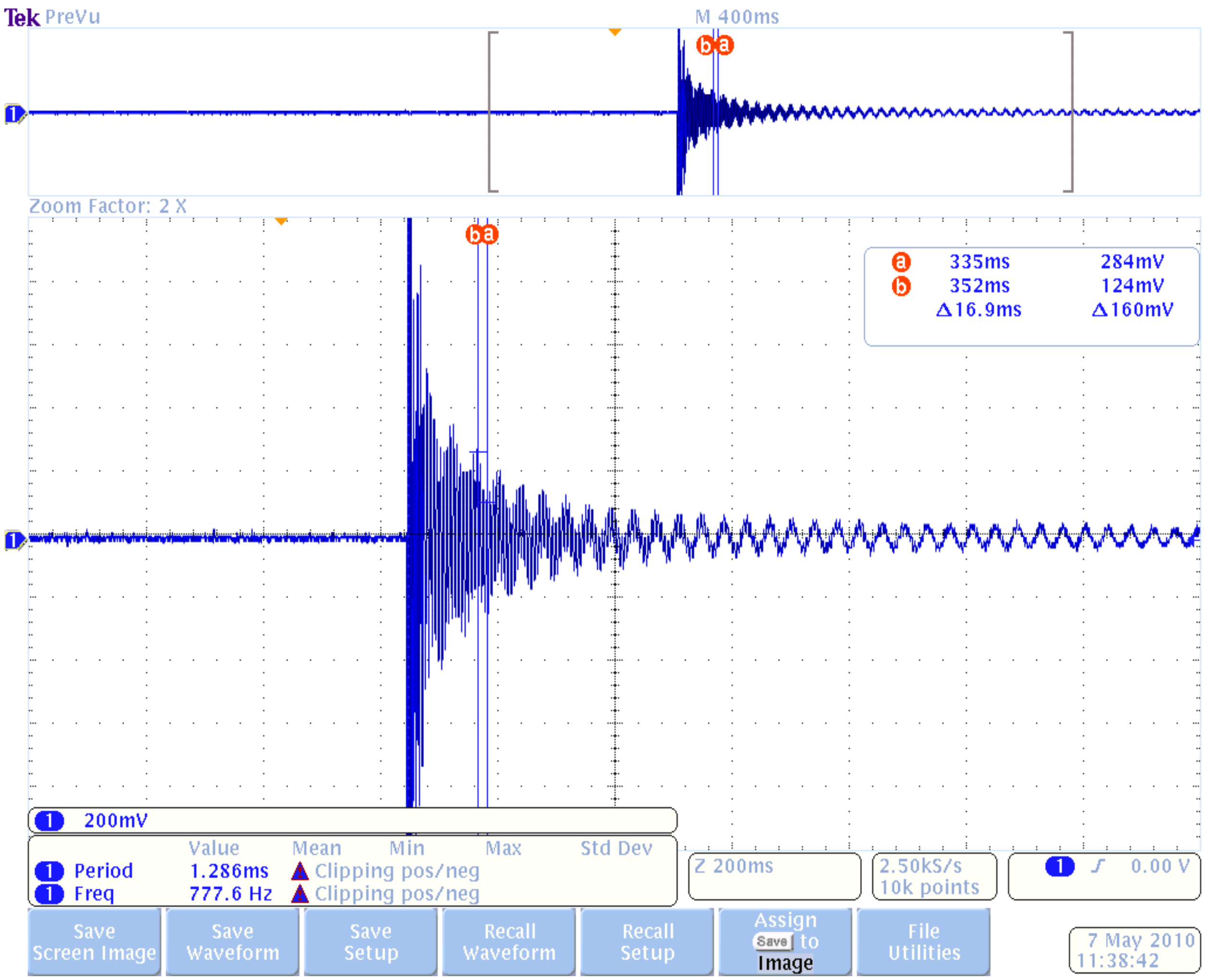

Fig 18: (Graph showing the damping of a mild steel beam with Teflon inserts)

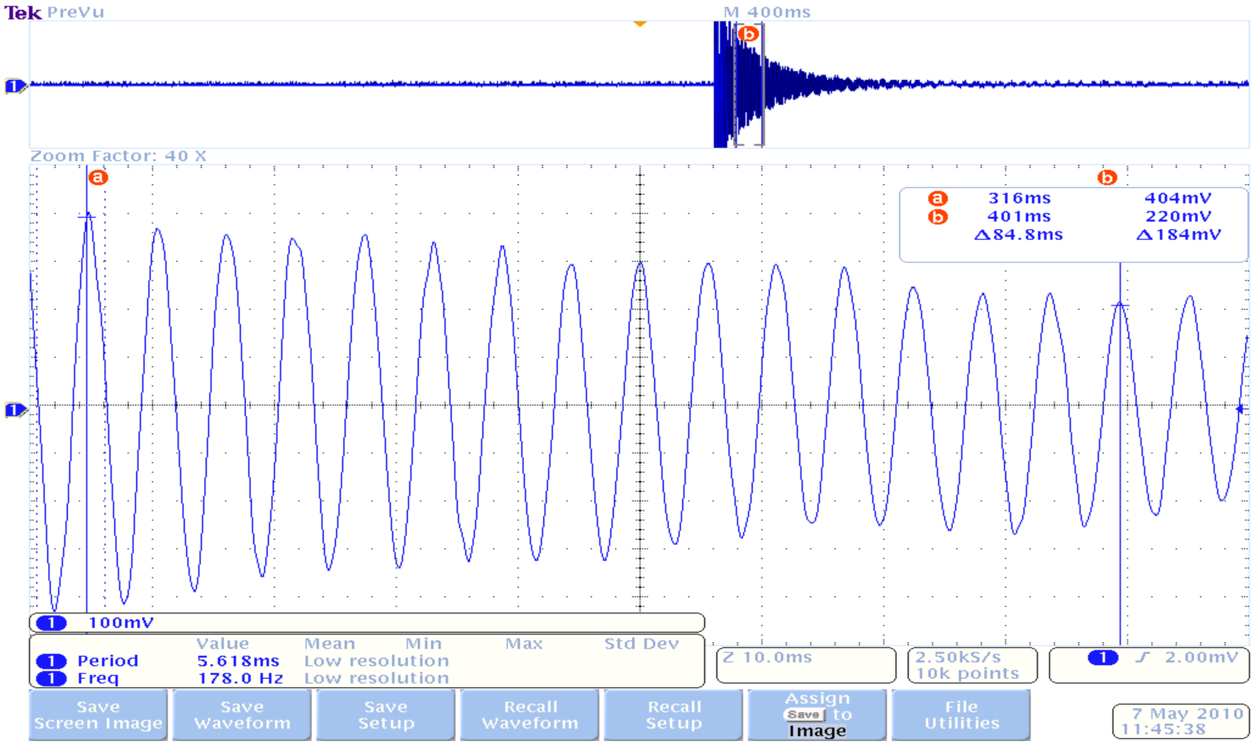

Fig 19: (section of Amplitude-Time graph of mild steel beam with Teflon inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_t = \frac{1}{n}\ln(y1/yn)$

From the Graph: 11 $y1$ = 404 mV

yn = 220 mV

n = 15

Hence, $\delta_t = \frac{1}{15} \ln \left(\frac{404}{220}\right)$

$\delta_t = 0.0405$

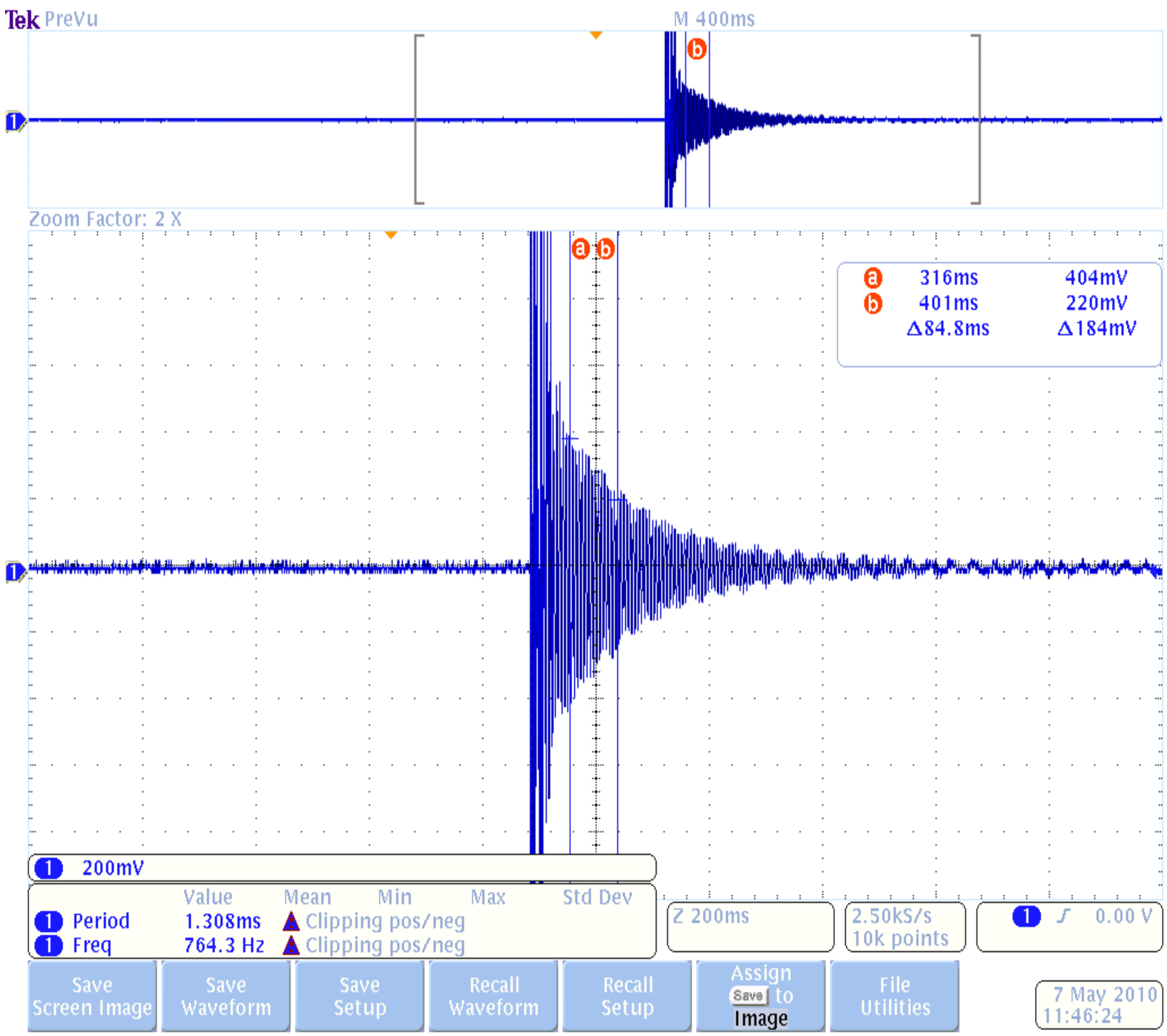

Fig 20: (Graph showing the damping of a mild steel beam with Teflon inserts)

Table 2:

OBSERVATION NO.	NATURAL FREQUENCY OF VIBRATION(hz)	TIME PERIOD (ms)	δ_t	MEAN δ_t
1	176.2	5.675	0.0595	0.0507
2	175.1	5.712	0.0521	
3	178.0	5.618	0.0405	

The logarithmic decrement of vibration of a mild steel beam with Teflon inserts is found to be

δ_t = **0.0507**

So the increase in the damping property of the beam due to Teflon inserts is $\Delta\ \delta_t = \delta_t - \delta_0$

From Table: 1 $\delta_0 = 0.0346$

From Table: 2 $\delta_t = 0.0507$

$\Delta\ \delta_t$ = **0.0161**

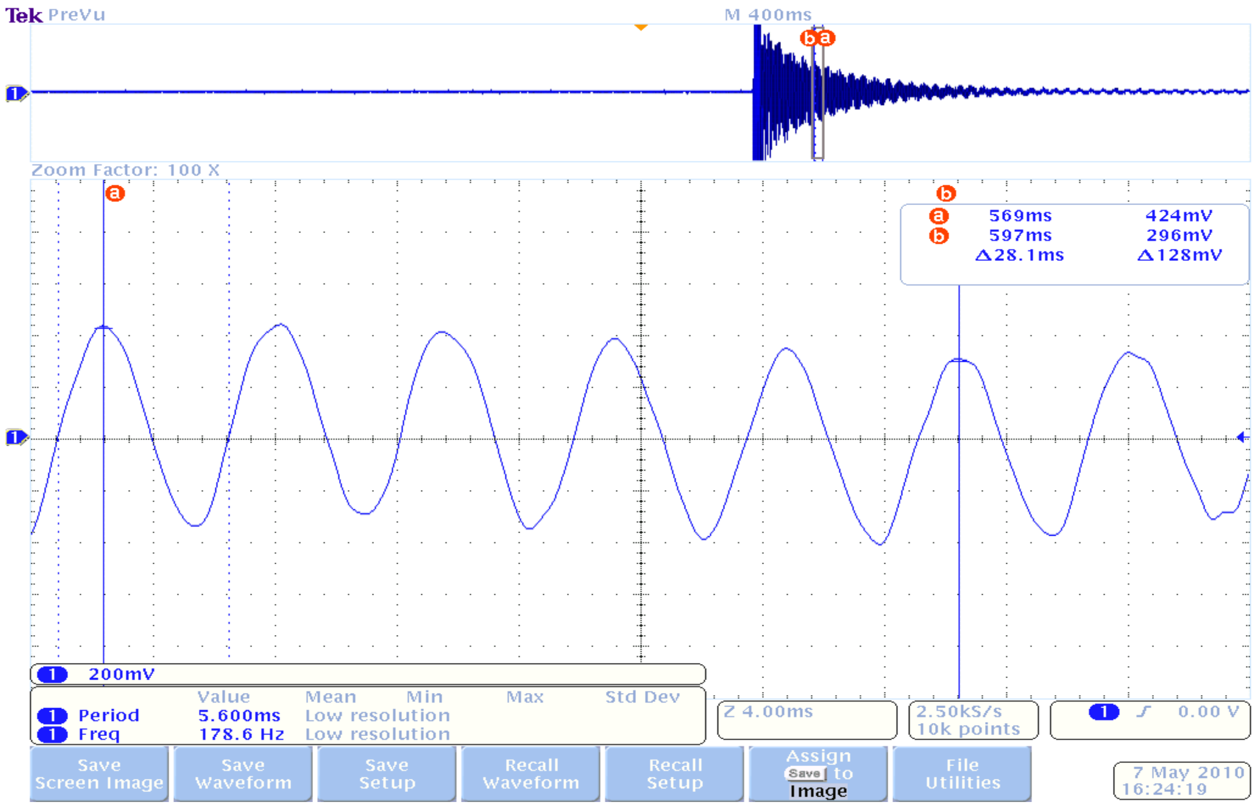

Fig 21: (section of Amplitude-Time graph of mild steel beam with Perspex inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_p = \frac{1}{n}\ln(y1/yn)$

From the Graph: 13 $y1$ = 424 mV

yn = 296 mV

n = 5

Hence, $\delta_p = \frac{1}{5} ln \left(\frac{424}{296}\right)$

$\delta_p =$ 0.0718

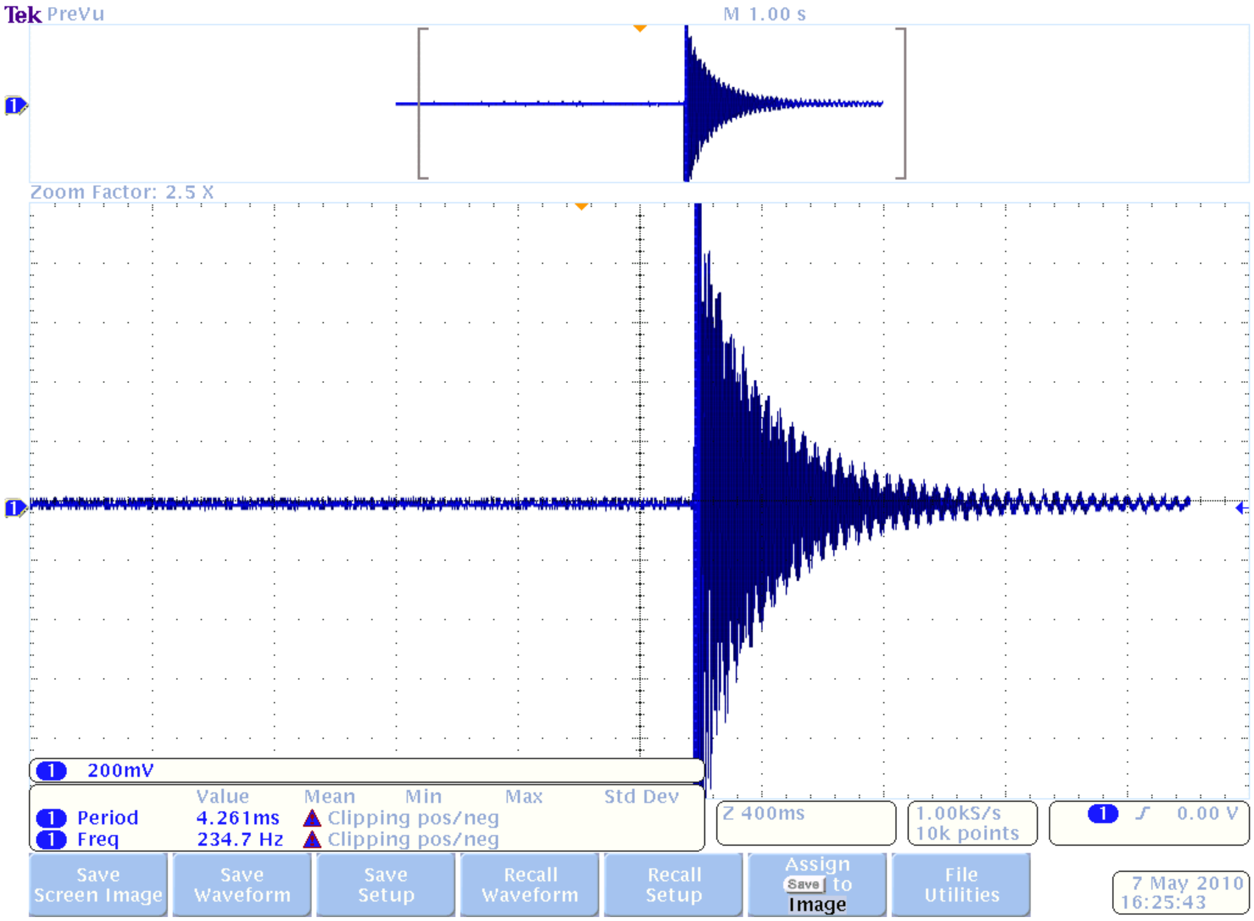

Fig 22: (Graph showing the damping of a mild steel beam with Perspex inserts)

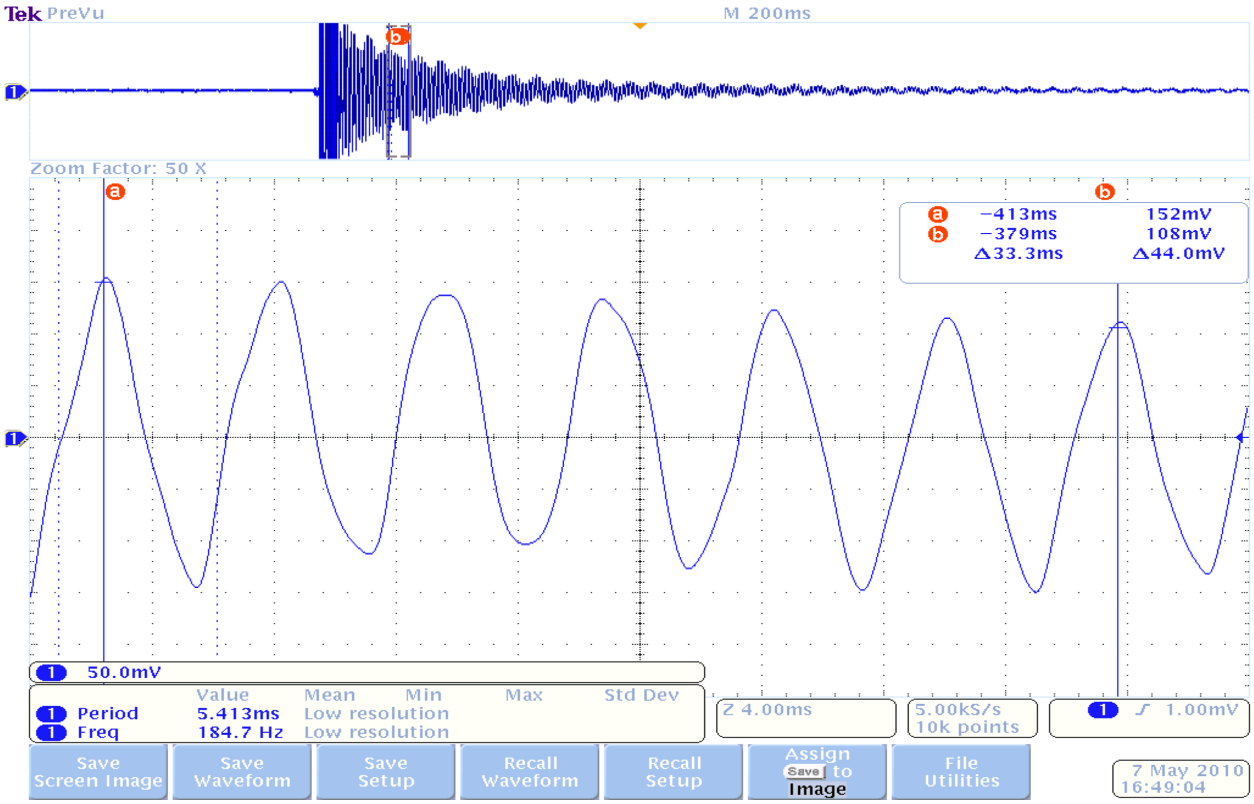

Fig 23: (section of Amplitude-Time graph of mild steel beam with Perspex inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_p = \frac{1}{n}\ln(y1/yn)$

From the Graph: 15 $y1$ = 152 mV

yn = 108 mV

n = 6

Hence, $\delta_p = \frac{1}{6} ln \left(\frac{152}{108}\right)$

$\delta_p =$ 0.0569

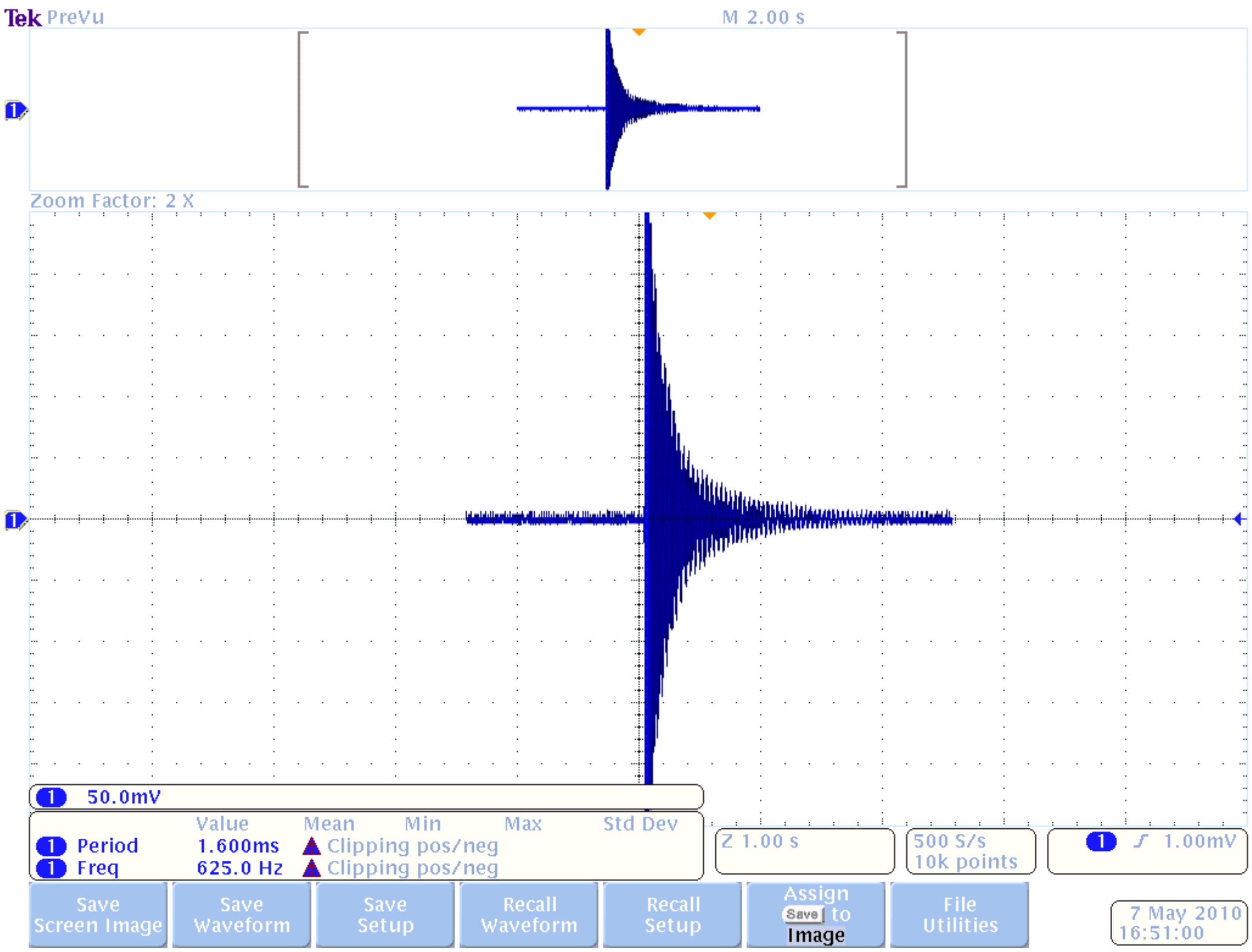

Fig 24: (Graph showing the damping of a mild steel beam with Perspex inserts)

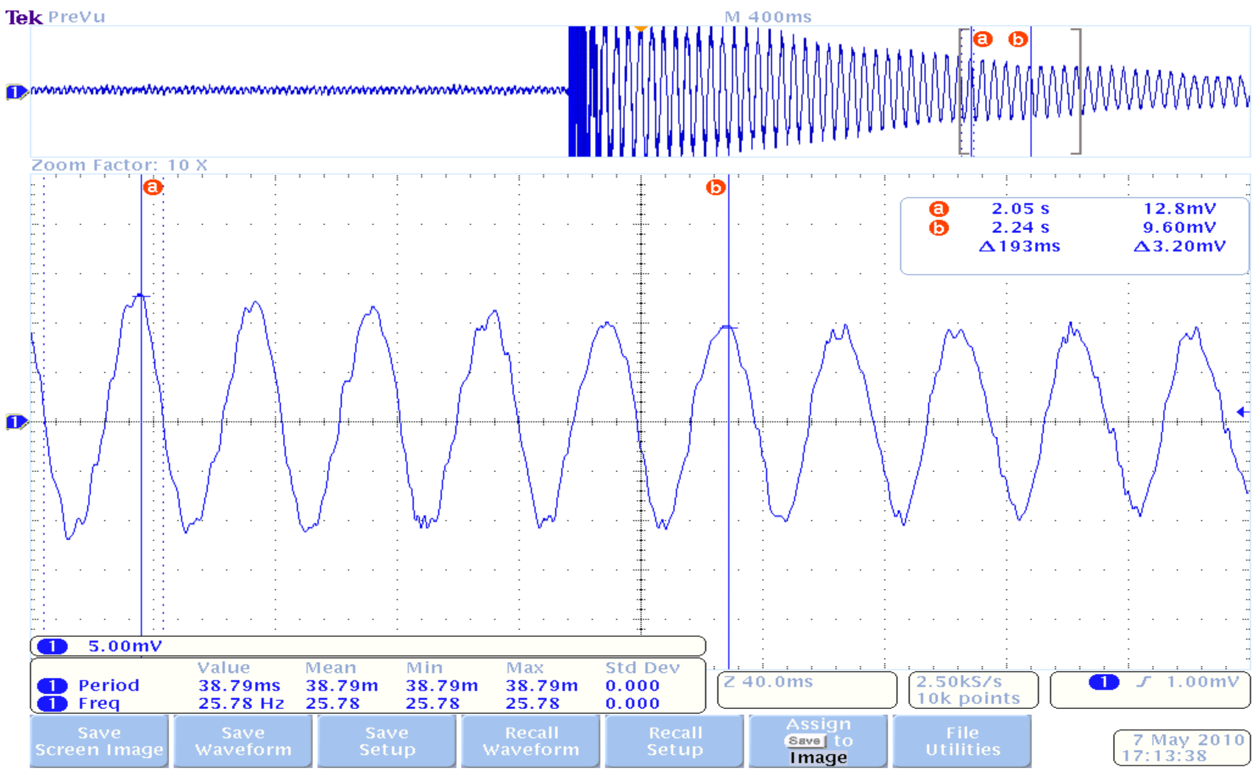

Fig 25: (section of Amplitude-Time graph of mild steel beam with Perspex inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_p = \frac{1}{n}\ln(y1/yn)$

From the Graph: 17 $y1$ = 12.8 mV

yn = 9.6 mV

n = 5

Hence, $\delta_p = \frac{1}{5} ln \left(\frac{12.8}{9.6}\right)$

$\delta_p =$ 0.0575

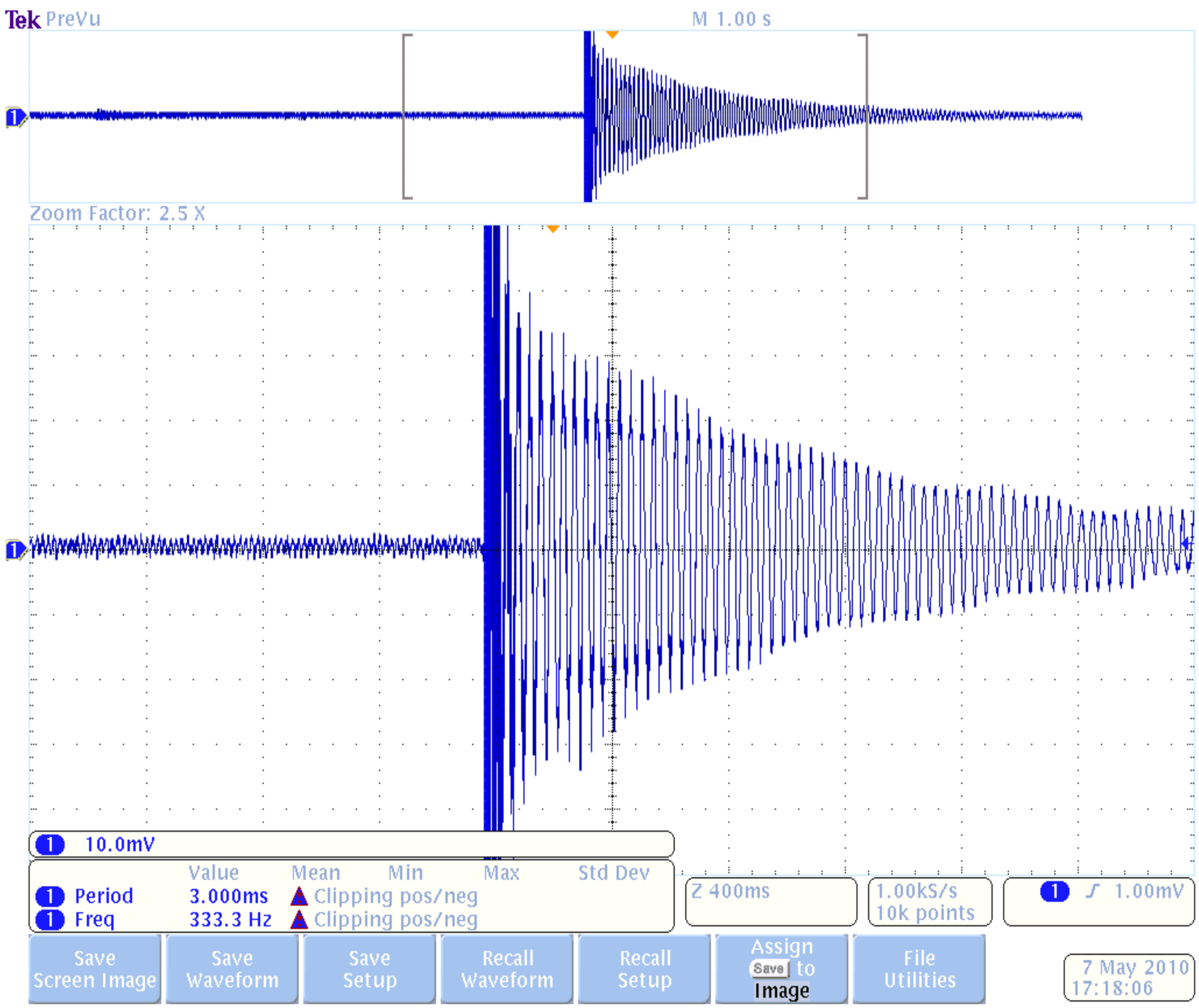

Fig 26: (Graph showing the damping of a mild steel beam with Perspex inserts)

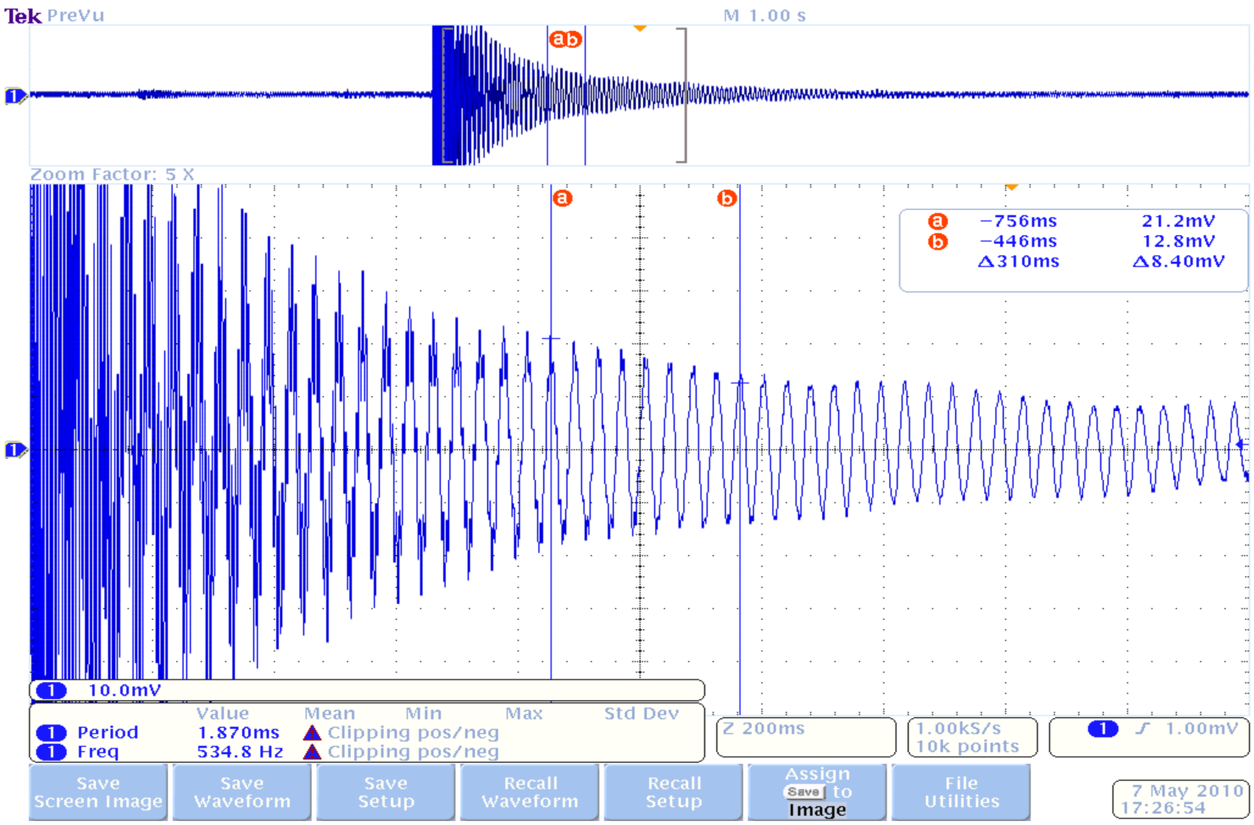

Fig 27: (section of Amplitude-Time graph of mild steel beam with Perspex inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_p = \frac{1}{n}\ln(y1/yn)$

From the Graph: 19 $y1$ = 21.2 mV

yn = 12.8 mV

n = 8

Hence, $\delta_p = \frac{1}{8} ln \left(\frac{21.2}{12.8}\right)$

$\delta_p =$ 0.063

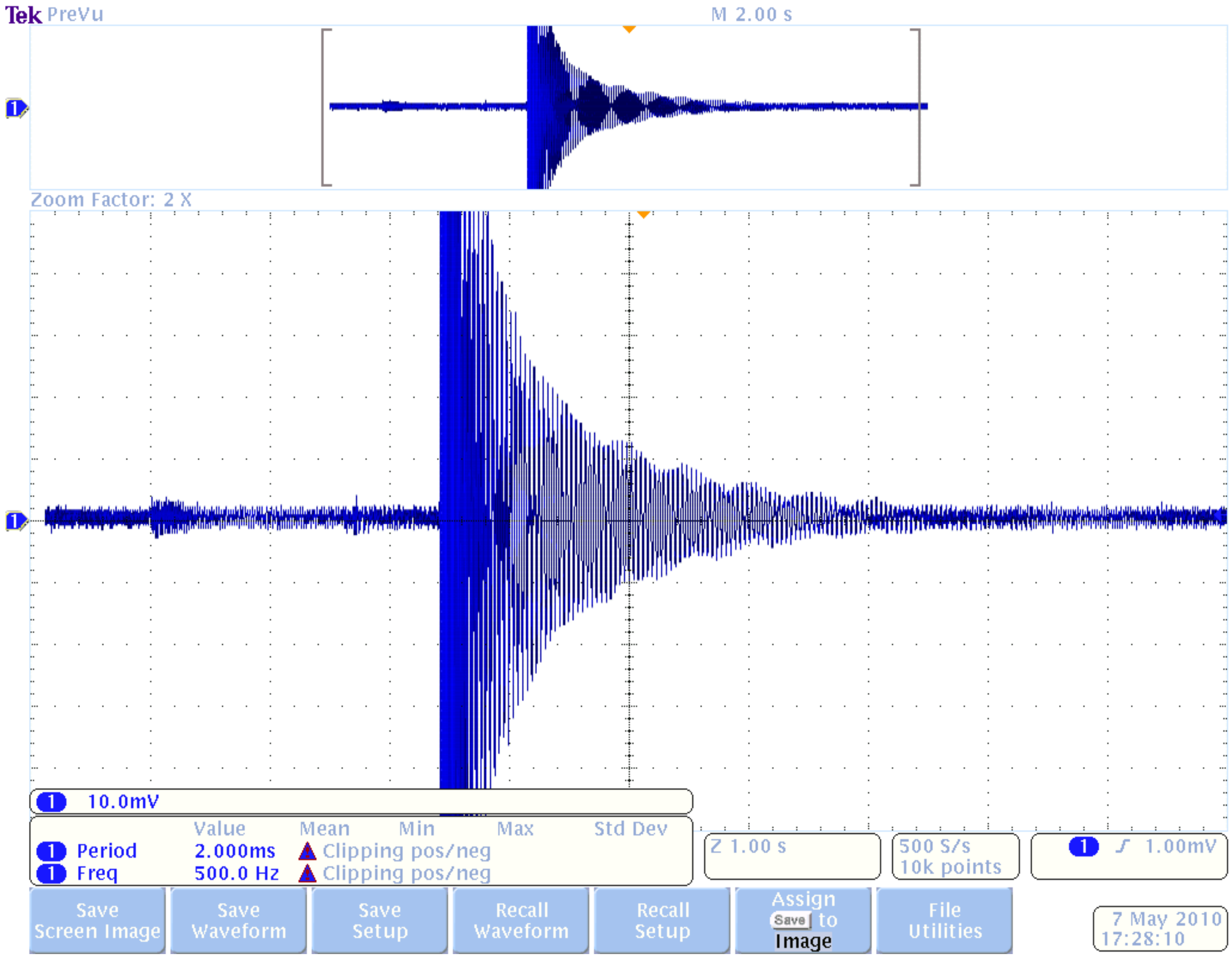

Fig 28: (Graph showing the damping of a mild steel beam with Perspex inserts)

Table 3:

OBSERVATION NO.	NATURAL FREQUENCY OF VIBRATION(hz)	TIME PERIOD (ms)	δ_p	MEAN δ_p
1	178.6	5.600	0.0718	0.0623
2	184.7	5.413	0.0569	
3	25.78	38.79	0.0575	
4	534.8	1.87	0.0630	

The logarithmic decrement of vibration of a mild steel beam with Perspex inserts is found to be

δ_p = **0.0623**

So the increase in the damping property of the beam due to Teflon inserts is $\Delta\ \delta_p = \delta_p - \delta_0$

From Table: 1 $\delta_0 = 0.0346$

From Table: 3 $\delta_p = 0.0623$

$\Delta\ \delta_p$ = **0.0277**

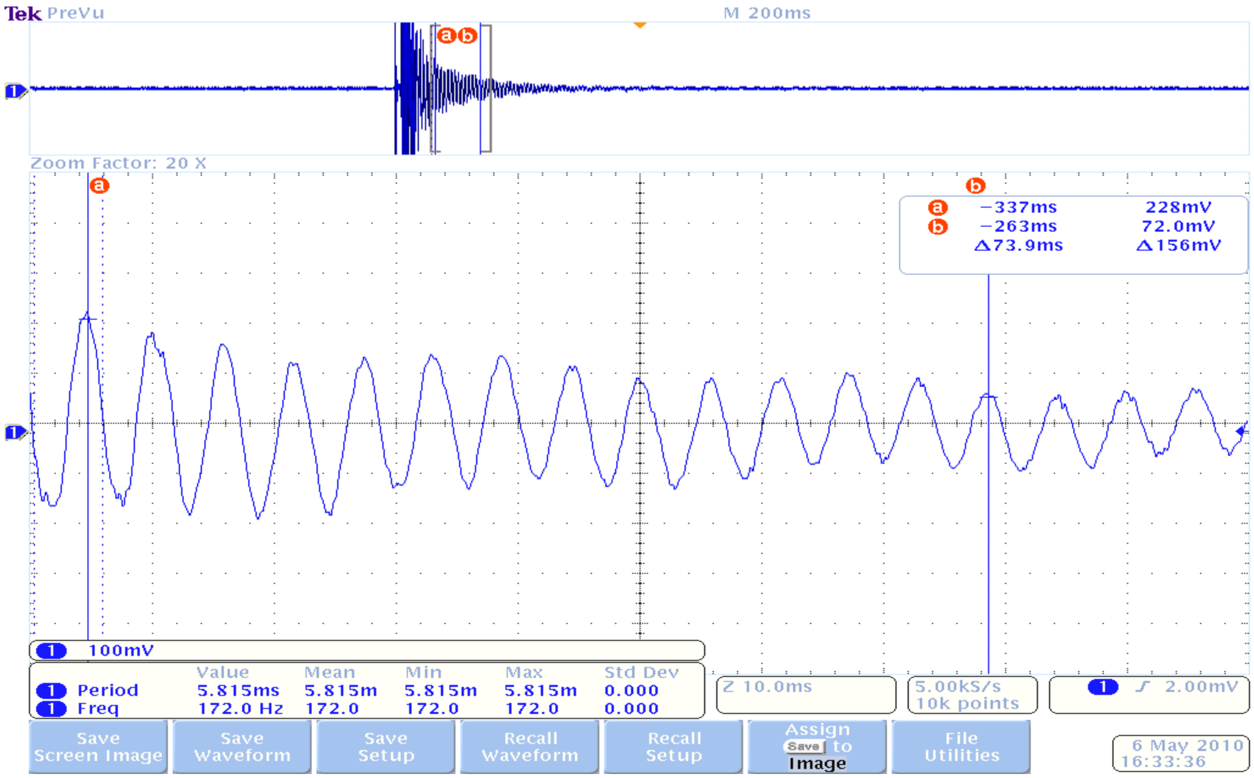

Fig 29: (section of Amplitude-Time graph of mild steel beam with Bakelite inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_b = \frac{1}{n}\ln(y_1/y_n)$

From the Graph: 21 y_1 = 228 mV

y_n = 72 mV

n = 13

Hence, $\delta_b = \frac{1}{13}\, ln \left(\frac{228}{72}\right)$

$\delta_b =$ 0.0887

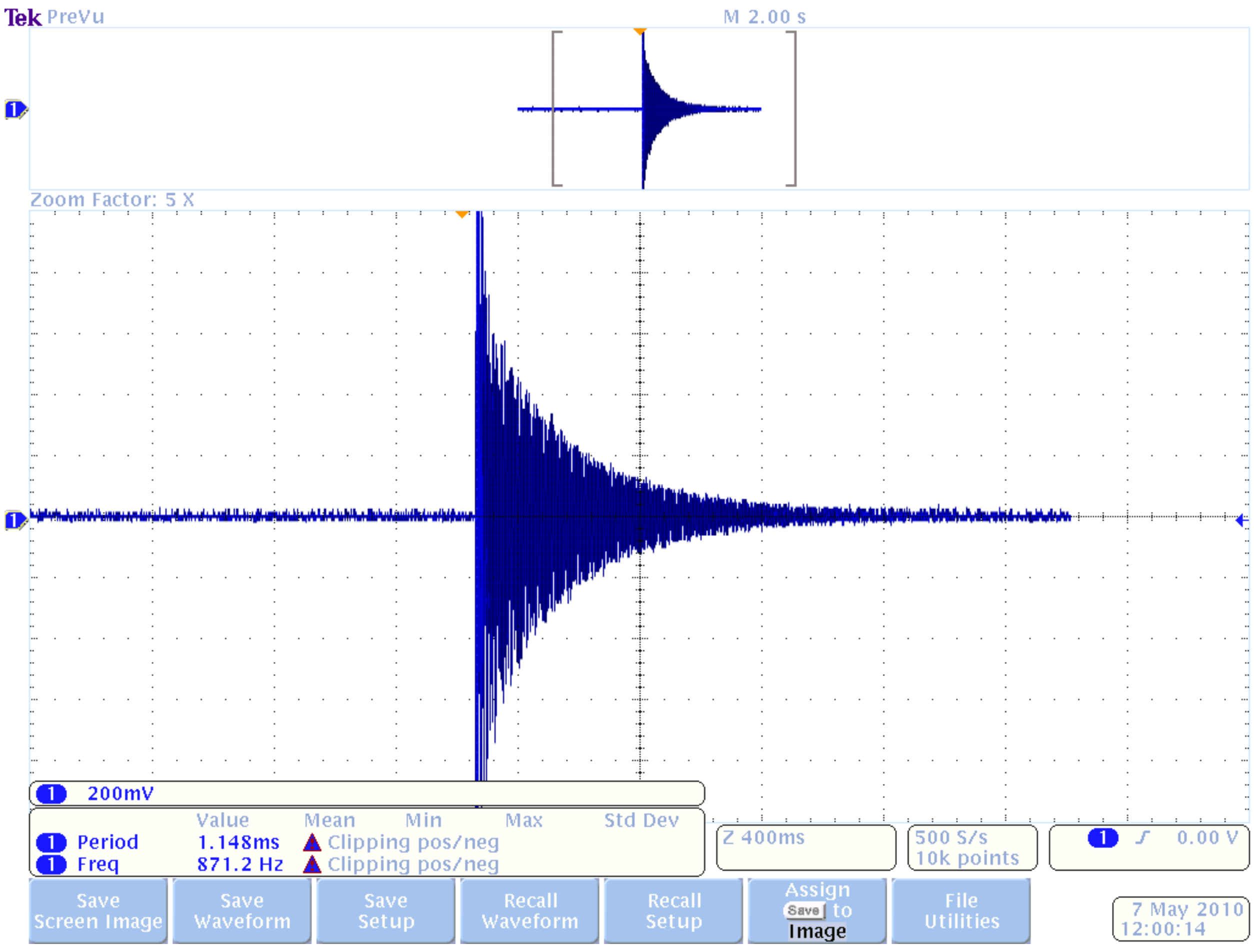

Fig 30: (Graph showing the damping of a mild steel beam with Bakelite inserts)

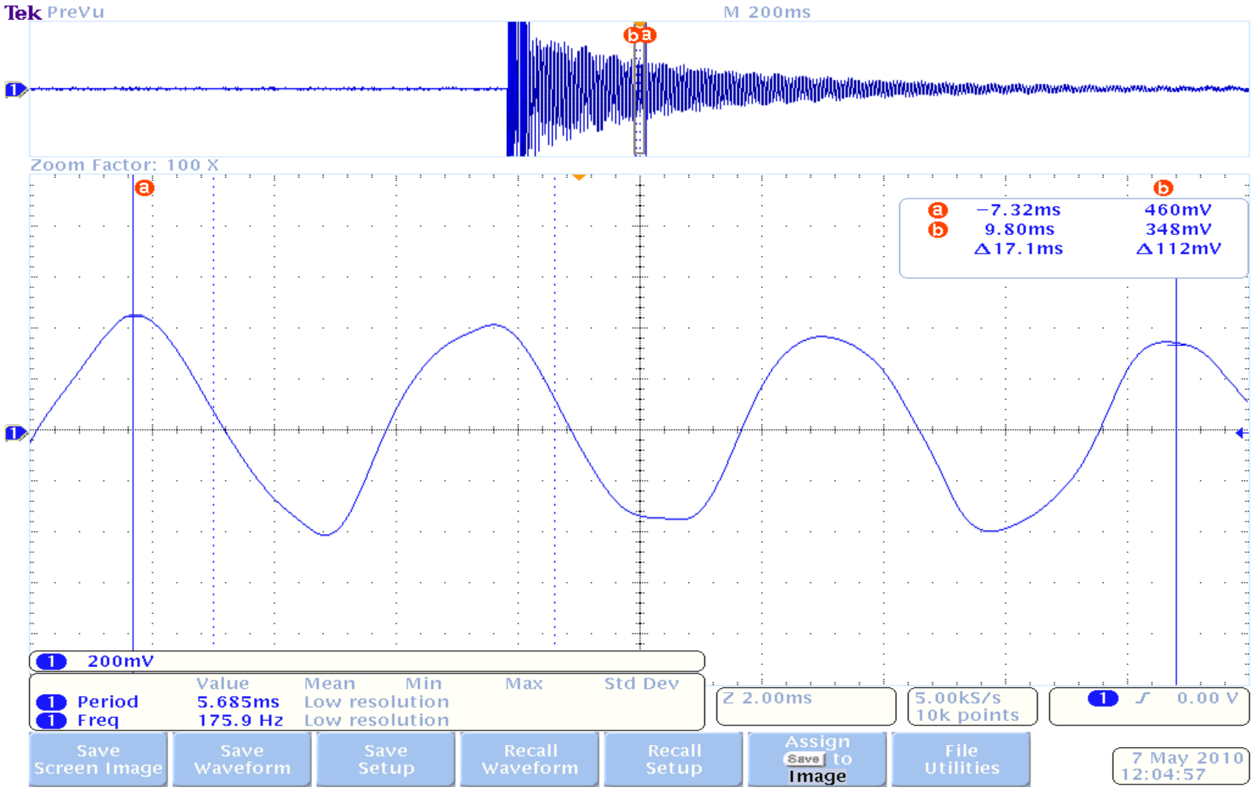

Fig 31: (section of Amplitude-Time graph of mild steel beam with Bakelite inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_b = \frac{1}{n}\ln(y1/yn)$

From the Graph: 23 $y1$ = 460 mV

yn = 348 mV

n = 3

Hence, $\delta_b = \frac{1}{3} ln \left(\frac{460}{348}\right)$

$\delta_b =$ 0.093

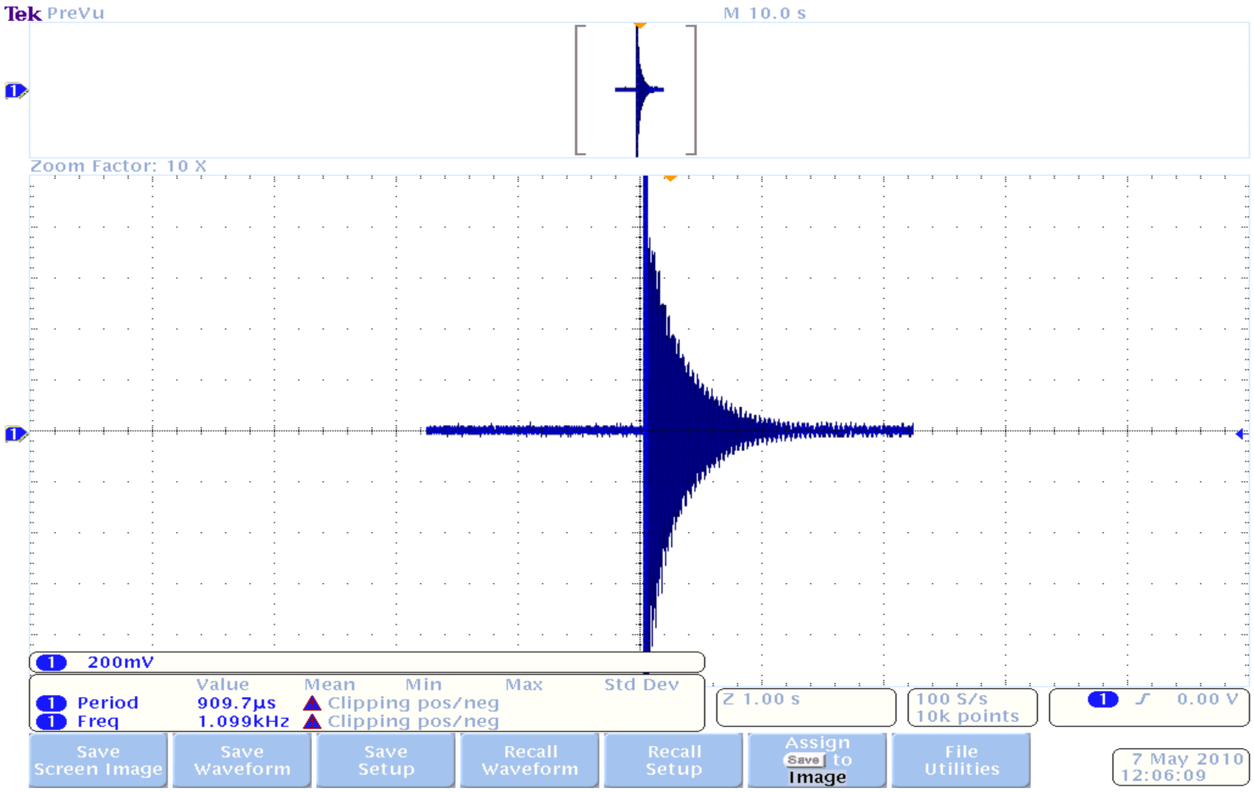

Fig 32: (Graph showing the damping of a mild steel beam with Bakelite inserts)

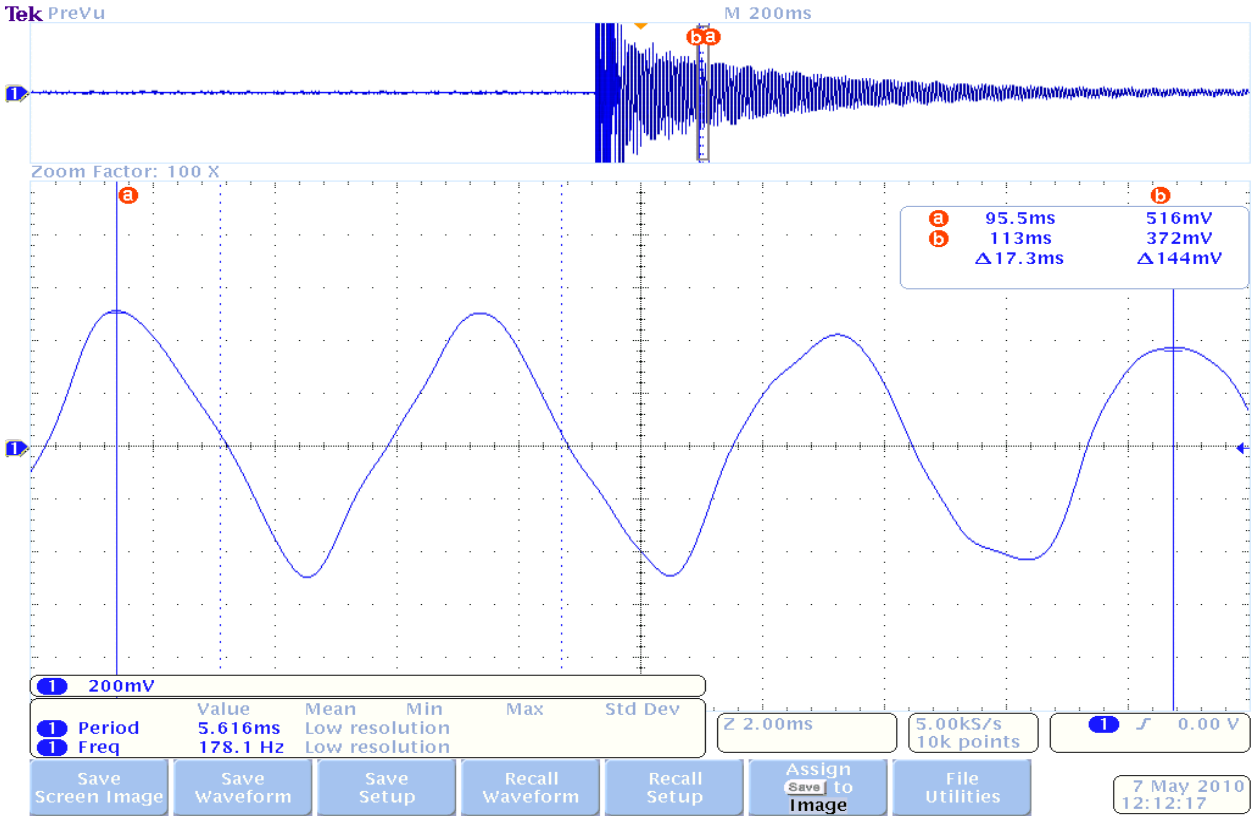

Fig 33: (section of Amplitude-Time graph of mild steel beam with Bakelite inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_b = \frac{1}{n}\ln(y1/yn)$

From the Graph: 25 $y1$ = 516 mV

yn = 372 mV

n = 3

Hence, $\delta_b = \frac{1}{3} ln \left(\frac{516}{372}\right)$

$\delta_b =$ 0.109

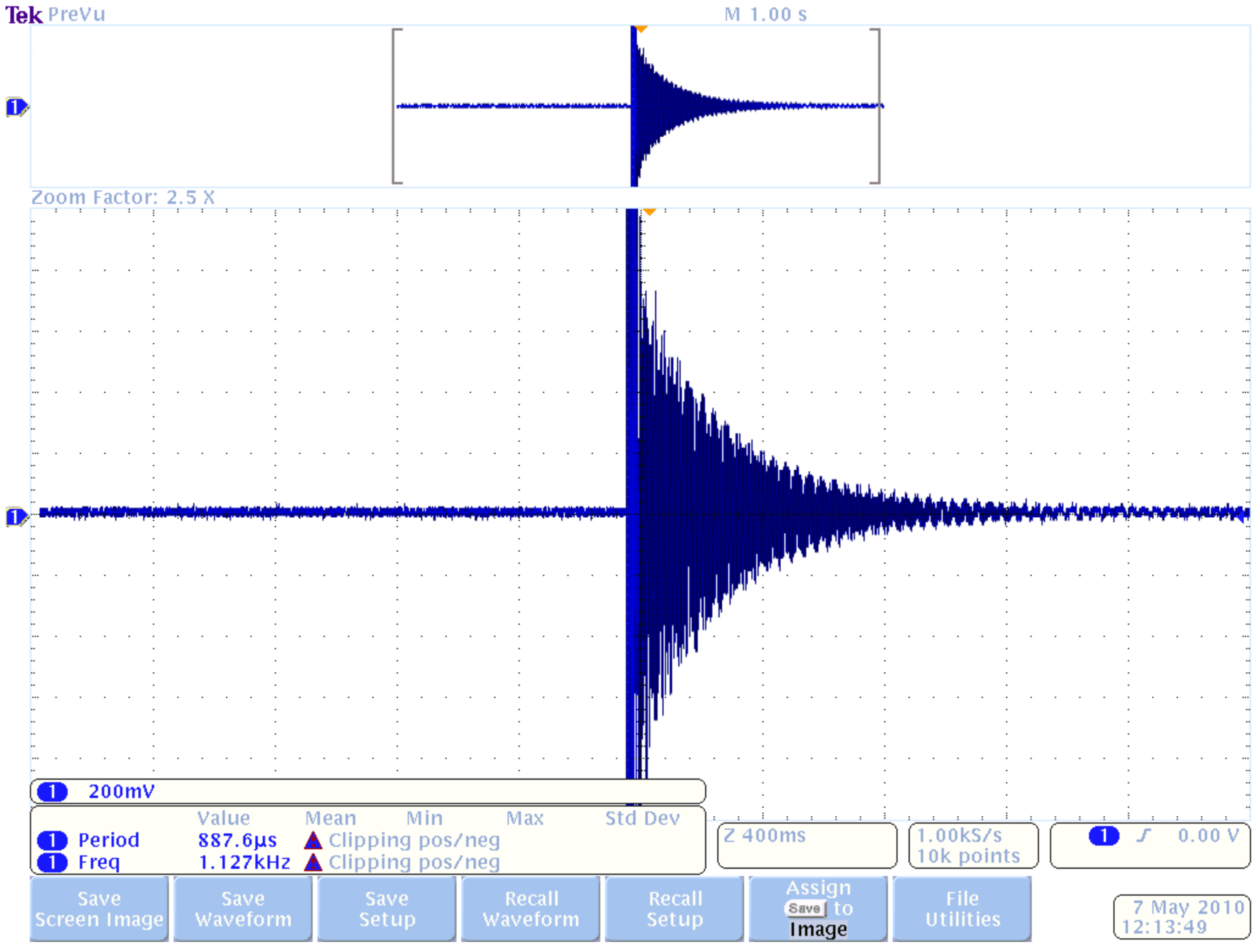

Fig 34: (Graph showing the damping of a mild steel beam with Bakelite inserts)

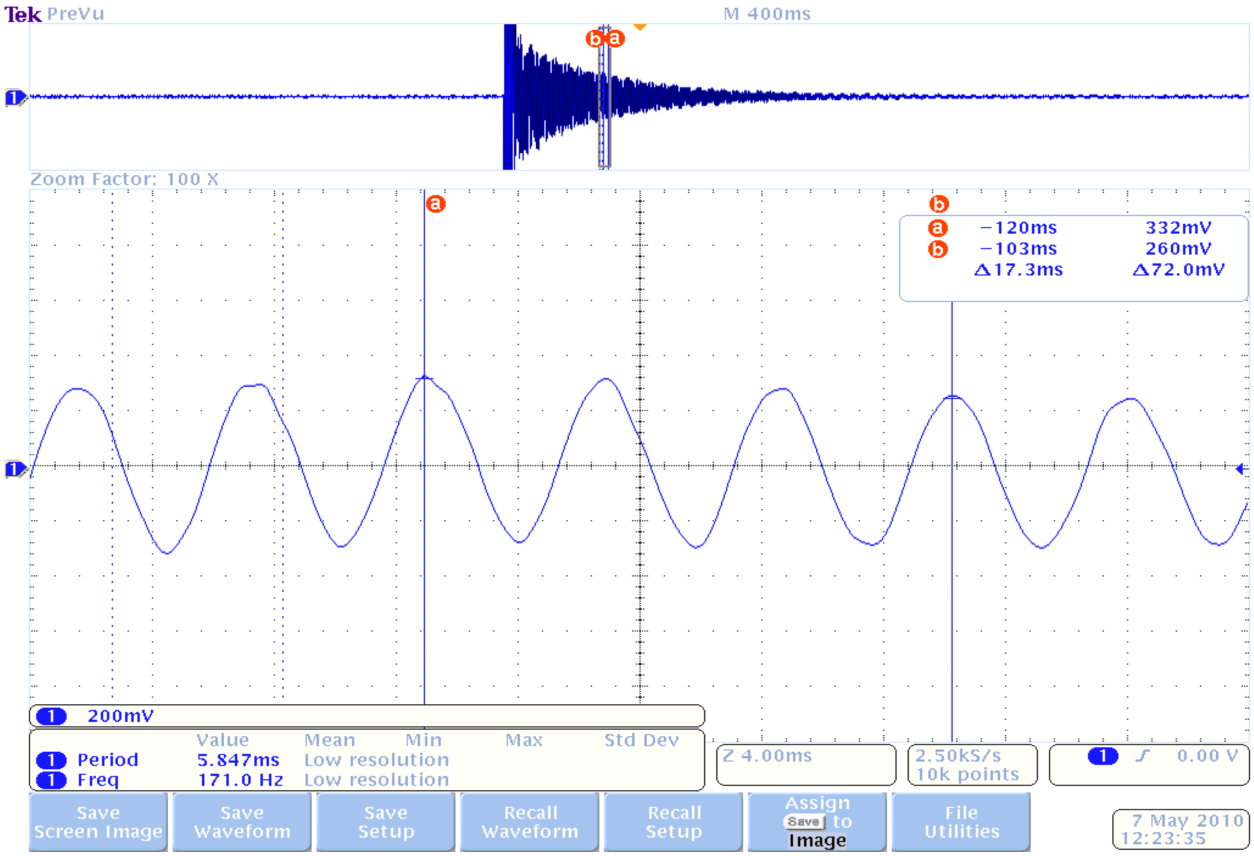

Fig 35: (section of Amplitude-Time graph of mild steel beam with Bakelite inserts)

The logarithmic decrement of amplitude of vibration for n-cycles: $\delta_b = \frac{1}{n}\ln(y1/yn)$

From the Graph: 27 $y1 = 332$ mV

$yn = 260$ mV

$n = 3$

Hence, $\delta_b = \frac{1}{3} ln \left(\frac{332}{260}\right)$

$\delta_b = 0.0814$

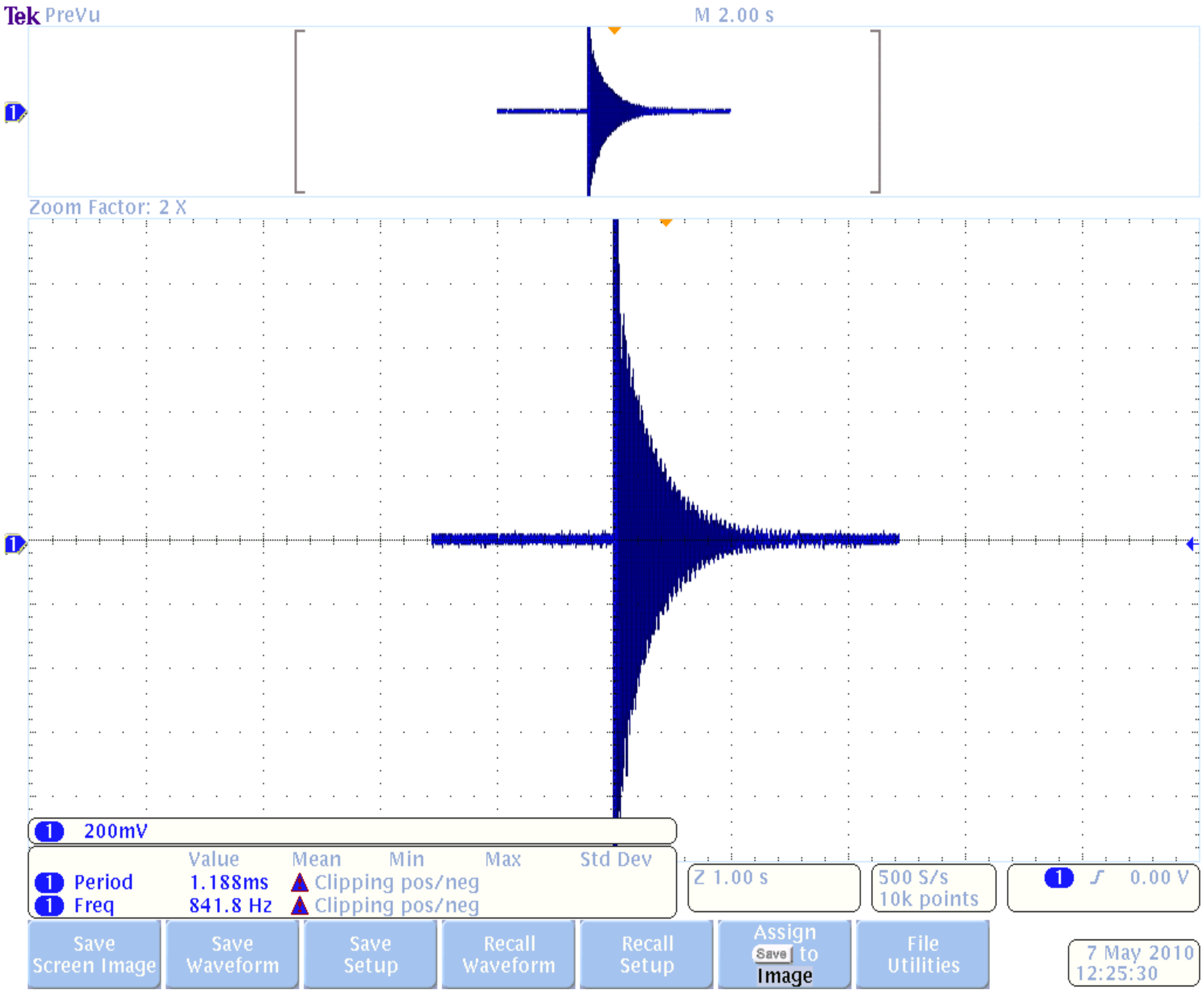

Fig 36: (Graph showing the damping of a mild steel beam with Bakelite inserts)

Table 4:

OBSERVATION NO.	NATURAL FREQUENCY OF VIBRATION(hz)	TIME PERIOD (ms)	δ_b	MEAN δ_b
1	172	5.815	0.0887	0.093
2	175.9	5.685	0.093	
3	178.1	5.616	0.109	
4	171	5.847	0.0814	

The logarithmic decrement of vibration of a mild steel beam with Perspex inserts is found to be

δ_b = **0.093**

So the increase in the damping property of the beam due to Teflon inserts is $\Delta\ \delta_b = \delta_b - \delta_0$

From Table: 1 $\delta_0 = 0.0346$

From Table: 4 $\delta_b = 0.093$

$\Delta\ \delta_b$ = **0.0584**

CHAPTER 5

CONCLUSION

CONCLUSION

Proper introduction of stress concentration into structural members can considerably increase their damping capacities and dynamic rigidities with minor sacrifice in their static rigidities. Better damping characteristics can be achieved when structural members are fitted elastic inserts of materials having higher damping capacities, almost without sacrificing any static rigidity or slightly compromising with strength of the structure. Proper combination of beam/strip and insert materials, the increase in damping could be high enough so as to offset the effect of stress concentration. So the inserts of high damping capability in the structures increases the damping characteristics of the structure.

From the experiment it is concluded that **Bakelite** inserts enhance the damping properties of the metal beam more than **Perspex** and **Teflon** inserts.

$\boldsymbol{\delta_b > \delta_p > \delta_t > \delta_0}$

$\Delta\ \delta_b = \mathbf{0.0584},\ \Delta\ \delta_p = \mathbf{0.0277},\ \Delta\ \delta_t = \mathbf{0.0161}$

The increase in damping property of the three types of inserts is in the following order:

$\boldsymbol{\Delta\ \delta_b > \Delta\ \delta_p > \Delta\ \delta_t}$

So the beam with Bakelite inserts shows the maximum damping property compared to other two (Perspex and Teflon).

References:

1. A. MALLIK and A. GHOSH, Improvement of dynamic rigidity of structural members with introduced stress concentration, Journal of Technology 13, 19-26, 1971.
2. A. MALLIK and A. GHOSH, Improvement Of Damping Characteristics Of Structural Members With High Damping Elastic Inserts, Journal of Sound and Vibration 27, 25-36, 1973.
3. R. RAMATHULLAH and A. K. MALLIK, Damping Of Cantilever Strips with Inserts, Journal of Sound and Vibration 66(1), 109-117, 1979.
4. B.K. NANDA, Study of Damping in Structural Members under Controlled Dynamic Slip, PhD Thesis, 1992.
5. B.K. NANDA AND A.K. BEHERA, Study On Damping In Layered And Jointed Structures With Uniform Pressure Distribution At The Interfaces, Journal of Sound and Vibration 226, 1999.
6. B.K. NANDA AND A.K. BEHERA, Damping In Layered And Jointed Structures, International Journal Of Acoustics And Vibration 5, 2000.
7. B.K. NANDA, A.K. BEHERA, Improvement Of Damping Capacity Of Structural Members Using Layered Construction, Seventh International Congress On Sound And Vibration, Garmisch-Partenkirchen, Germany, 2000.
8. W. DE CLARENCE, SILVA, and Vibration: Fundamentals And Practice, Boca Raton, FL: CRC Press, Cop. 2000.
9. B BHATTACHARYA, G R TOMLINSON, J R HOUSE, Vibration Suppression of Structures with Viscoelastic Inserts, MS Thesis, 2002.

10. C. Cai, H. Zheng, M. S. Khan and K. C. Hung, Modeling of Material Damping Properties in ANSYS, CADFEM Users´ Meeting & ANSYS Conference, 2002.

11. D.I.G. Jones, The impulse response functions of a damped single degree of freedom system, Journal of Sound and Vibration 106 353-356, 1986.

12. P. Lemerle, Measurement of the Viscoelastic Properties of Damping Materials: Adaptation of the Wave Propagation Method to Tests Samples of Short Length. Journal of Sound and Vibration. 250: 2:181-196, 2002.

13. L. MEIROVITCH, Elements of Vibration Analysis, McGraw hill publication, 1975.

14. C M HARRIS and C E CREDE Shock and Vibration Handbook McGraw-Hill.

15. W. T. THOMSON, Vibration Theory and Applications.

16. S. P. TIMOSHENKO and J. N. GIDDIER Theory of Elasticity. McGraw-Hill.

17. http://home.um.edu.mt/auxetic/properties.htm

18. http://www.mfg.mtu.edu/cyberman/machtool/machtool/vibration/damping.html

19. http://www.wikipedia.org/

20. http://www.deicon.com/vib_categ.html